Physics Investigation - What factors affect the efficiency of siphoning?

- **Research & Rationale**:

I have chosen to investigate siphoning because as a kid I was always intrigued and puzzled by this "phenomena" when I used to clean my fish tank. The difficulty factor also played a major role. I wanted to do something which could be carried out comfortably in a relatively short time. An investigation, which is not so demanding on the practical side to allow more time for processing of the data captured.

On a more scientific note I am interested in mechanics of fluids. This interest was enforced last year when I had the opportunity to attend a lecture on fluid mechanics at P&G. At the conference I greatly expanded my knowledge regarding the physical aspect of fluids and their properties. In last year's AS course we have met a topic in this field. I will be applying ideas and knowledge gathered from last year for this investigation. I will also be looking at more complex concepts and ideas such as Reynolds's number, the effect of temperature on viscosity and liquid density, which we have not met in last year's course.

The areas I will be looking into are as follows:

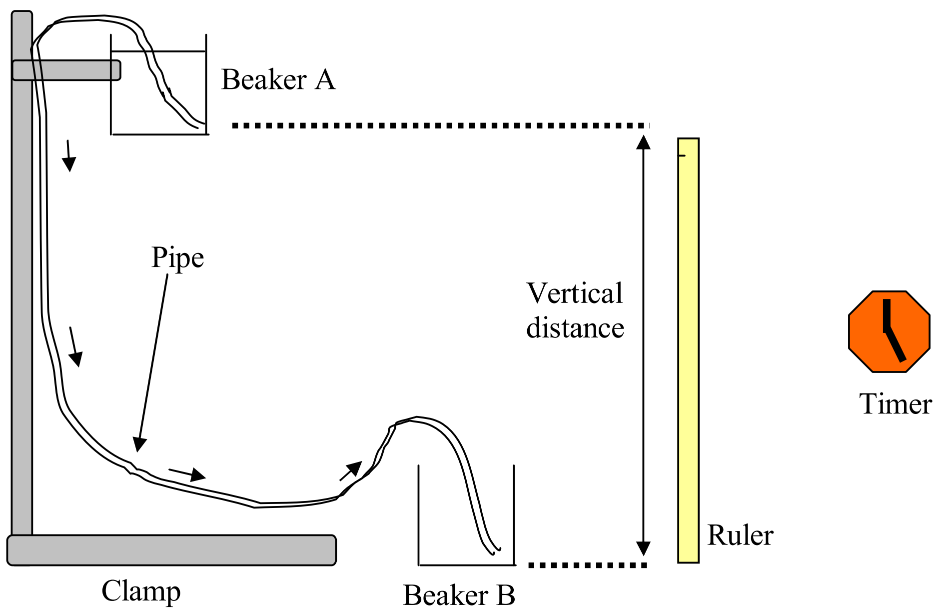
1) The effect of the **Pipe Diameter** on flow rate.
   - the effect of Pipe Diameter on liquid flow (turbulent/laminar)
2) The effect of **Temperature of liquid** on flow rate.
   - the effect of Temperature on liquid flow (turbulent/laminar)
3) The effect of the **Vertical height between source and destination of the fluid** on flow rate.
   - the effect of Vertical height on liquid flow (turbulent/laminar)
4) The effect of the **Liquid's Viscosity/Density** on flow rate.
   - the effect of Viscosity on liquid flow (turbulent/laminar)

I have consulted my teachers for guidance and I have also looked very carefully into the "the Suggestions papers" which contain many possible investigations which have been done in the past. I opted to choose neither of them but many aspects I will be looking into in my investigation are similar to those in the papers. The school library has many resources to our availability, which proved helpful in obtaining certain formulas and relations, which I will be applying in my work. The Internet was also a great source for information and with the aids of online audio-visual presentations I was able to understand complicated ideas such as Archimedes law etc.

All the apparatus that I will be needing is readily available at school but prior to this knowledge I had stopped at the local aquarium store to check the availability and range of pipe sizes that will obviously be needed to carry out my investigation.

- **Planning:**

Apparatus - 2 Beakers
4 plastic pipes (differing diameter)
Clamp + bosses
Timer
Ruler
Water bath
Thermometer



A pilot run was carried out to make sure that no problems crop up while during the actual investigation. The pilot run was not designed to extract accurate readings but was more of a guide to make the design of the practical as efficient as possible in the real thing.

I carried all 4 points to investigate. I tested the siphoning process using extreme values as the variable. For example to test the effect of pipe diameter on water flow I compared the results of the smallest tube against the largest tube. The same goes for temperature. I only used extreme temperatures, hot and cold water. As for vertical height I made the vertical difference as large as possible.

The only exception out of the 4 points is liquid viscosity/density. At the time I had not decided what liquids to use which have a differing viscosity value than water. I diluted honey in water but this was disastrous because the honey just sank to the bottom of the beaker and clogged up the pipes and left a big mess! So I ended up using tap water and distilled water for my pilot. The difference in water density is minimal but to my surprise the denser liquid **did** take slightly longer to be displaced. But such a small variation was never capable of producing conclusive results so this has still to be confirmed in the real thing.

As for the viscosity coefficient I intended to work this out myself by using the standard way to find this. This is the *Falling Ball viscometer*. This works by timing the ball falling at constant speed through the liquid. The problem with this is that the liquids I will be using are relatively “runny”.

(Using a too viscous liquid would result in the siphon not working at all!) This meant that the ball reaching the bottom of the measuring cylinder before the ball was travelling at a constant speed. I tried to use longer measuring cylinders but the same happened. By the time the ball reached the bottom the ball was still accelerating. This was no good so after discussing this with my teacher I decided that the easiest way out was to take viscous values out of a book.

The beakers used to hold the liquids have a capacity of 400ml. This should be enough liquid to obtain enough variation in my results. In the pilot run I used only 200ml and found out that 200ml of liquid was displaced rather quickly especially with the larger pipes so a larger volume should give a wider range of results. Beaker A will be held by a clamp onto the stand while beaker B will be put on the tables' work face. Beaker A can be moved either downwards or upwards if vertical height is to be altered. To keep the streamline the same for the different pipe elastic bands will be used to hold the pipe firmly to the stand's vertical pole.

The supplied pipes by the school were of varying length and this would have caused unfair results. So I had to cut all the other pipes to a fixed length. The chosen standard length is 1m 30. The four different pipes used are of varying diameter; these are as follows: 3 mm, 5 mm, 7 mm and 9 mm.

The pipe's diameter was measured using Vernier Calipers. The Vernier Calipers had to be calibrating prior to carrying out measurements. The percentage error carried on these instruments is so small that can be considered to be negligible.

So I had four points to investigate, these were the effect of siphoning by changing:

1) Pipe Diameter
2) Temperature of liquid
3) Vertical height between Beaker A & B
4) Liquid Viscosity/density

In each case I had to identify a way to change one factor without changing any other one to carry out a fair run.

Factor to change:	**Manner to do so:**
Pipe Diameter	Swap pipes.
Temperature of liquid	Using a hot bath to set liquid temperature.
Vertical height between Beaker A & B	By altering the distance between beaker A and B on the clamp.
Liquid Viscosity	Swap liquid used.

<u>Safety</u>

There are several issues that need attention regarding safety.

1) Since the siphon will be started off by myself some of the liquid may come in contact with my mouth. This is fine if the liquid used is water but other liquids may be poisonous. To reduce the chances of a fatal accident I will be using safe liquids which do not pose any

dangers to myself. I will also be doing the test regarding the change of liquid viscosity last so I won't have to reuse the tubes after putting chemicals through them. Another reason for using non-toxic chemicals is to prevent the plastic tubes from deforming/ becoming damaged.

2) When using temperature as the variable liquids at high temperature will be too hot to handle with bare hands. So a cotton glove will be used to fix the beaker containing the hot liquid in place.

3) The pipe leading to the bottom beaker should attached to beaker with some kind of adhesive such as Blue-tack because as the beaker fills up the plastic tube will float and fall out of the beaker resulting in spillages. This could be hazardous if liquids end up everywhere on the floor. This happened in the pilot run, the pipe floated, fell out of the beaker and water was spilled everywhere!

These where the results obtained in the pilot run:

Pipe Diameter:

Time taken to displace 200 ml of water through a:			
	Run #1	Run #2	Run #3
5 mm diameter pipe:	*19 seconds*	*21 seconds*	*18 seconds*
9 mm diameter pipe:	*8 seconds*	*6 seconds*	*5 seconds*

The results show as predicted that the larger pipe can displacement water a larger rate than the smaller pipe. However the times were not consistent. This shows that I'm not carrying out the practical to the accuracy needed. I will be striving to try and reduce the range of results obtained. In the real thing I will be calculating the flow rate rather then show the times but as this is just a pilot run this was necessary.

Liquid Temperature:

Time taken to displace 200 ml of water using a 3mm pipe at:			
	Run #1	Run #2	Run #3
*18*C*	*56 seconds*	*53 seconds*	*54 seconds*
*88*C*	*45 seconds*	*46 seconds*	*43 seconds*

The results were more or less consistent this time but in the real thing I will be trying to cut down the range of results even further. The results confirmed my prediction which is the warmer liquid will be displaced faster then the colder one. One modification I will be doing in the real thing when it comes to holding warm liquids is to insulate the beaker with foil. This is to keep the temperature from decreasing while the water is being displaced. Although the temperature drop is likely to be minimal I would like to be as fussy as possible to obtain accurate results.

Vertical height between Beaker A & B:

Time taken to displace 200 ml of water using a 3mm pipe with:			
	Run #1	Run #2	Run #3
27cm vertical distance	*79 seconds*	*79 seconds*	*80 seconds*
80 cm vertical distance	*30 seconds*	*31 seconds*	*30 seconds*

The results showed that the water was displaced at a faster rate with a large vertical distance then a small distance. I was very glad with these results because the readings variation is only 1 second which his pretty good going and shows that results are consistent.

Liquid Viscosity:

Time taken to displace 200 ml of water:			
	Run #1	Run #2	Run #3
Tap	*13.82 seconds*	*13.89 seconds*	*13.80 seconds*
Distilled	*13.21 seconds*	*14.00 seconds*	*13.09 seconds*

Out of the 4 points covered this was possibly the worst one. I predicted that the distilled water would be transported faster then the tap water, In two if the runs this was the case but in run 2 the distilled water actually took longer to be displaced than the tap water. The reason for this is because the variation between the two liquids is so small that a slight incompetence in the practical would result in the wrong figures. In the real thing I'll be using different liquids with a larger difference in density.

Preliminary Testing:

I decided to go through the factors I was investigating to make sure that in my final run I won't encounter any problems and to try and improve my practical skills. This is also the best way to see how I could alter my equipment for a better use.

I. The effect of Pipe Diameter on flow rate:

Factors to keep constant:

Liquid Temperature:	20*C
Vertical Height:	0.50 m
Liquid Volume:	300 ml
Liquid used:	Tap water

Results:

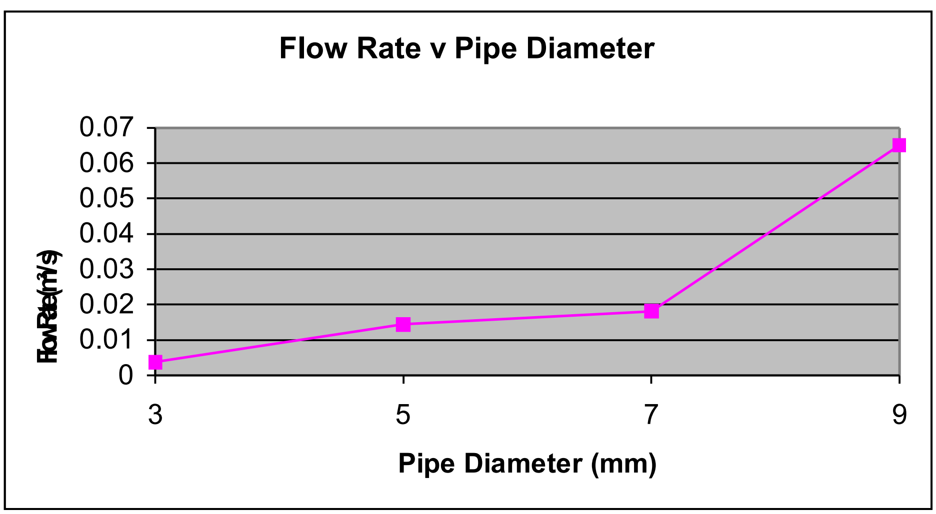
Pipe Diameter	Run #1	Run #2	Run #3
3 mm	80.00 s	81.00 s	81.00 s
5 mm	20.63 s	21.00s	20.98 s
7 mm	16.40 s	16.32 s	16.90 s
9 mm	4.62 s	4.69 s	4.51 s

Average readings:

Pipe Diameter	Average Reading
3 mm	80.00 s
5 mm	20.87 s
7 mm	16.54 s
9 mm	4.61 s

Flow Rate:

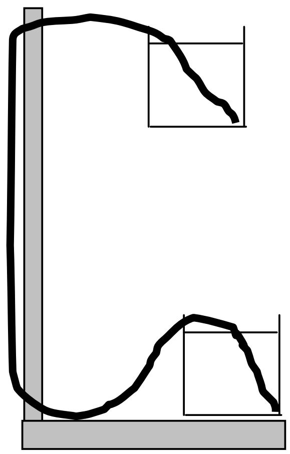
Pipe Diameter	Flow rate
3 mm	0.00375 m^3 / s
5 mm	0.01437 m^3 / s
7 mm	0.01814 m^3 / s
9 mm	0.06508 m^3 / s



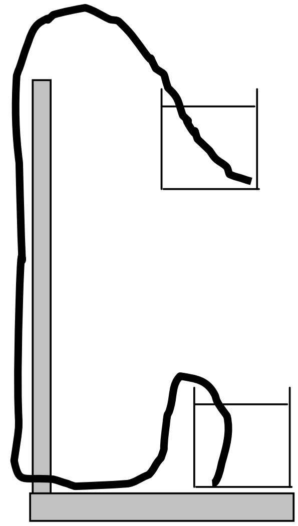
The Flow rate increases as expected with increased pipe diameter. However there is a very large increase in flow rate between a 7 and a 9 mm pipe compared with other increase. Since the increase in pipe size is constant I would have expected the flow rate to increase by the same amount for each pipe increase (a straight line)

This could be due to inconstancy in my work. These are the changes I will be making for the final test to try and make my practical a fairer test.

As I change the tube used to test the flow rate with greater diameters its is possible that the tube's path is not exactly the same as the previous pipe. Ex:

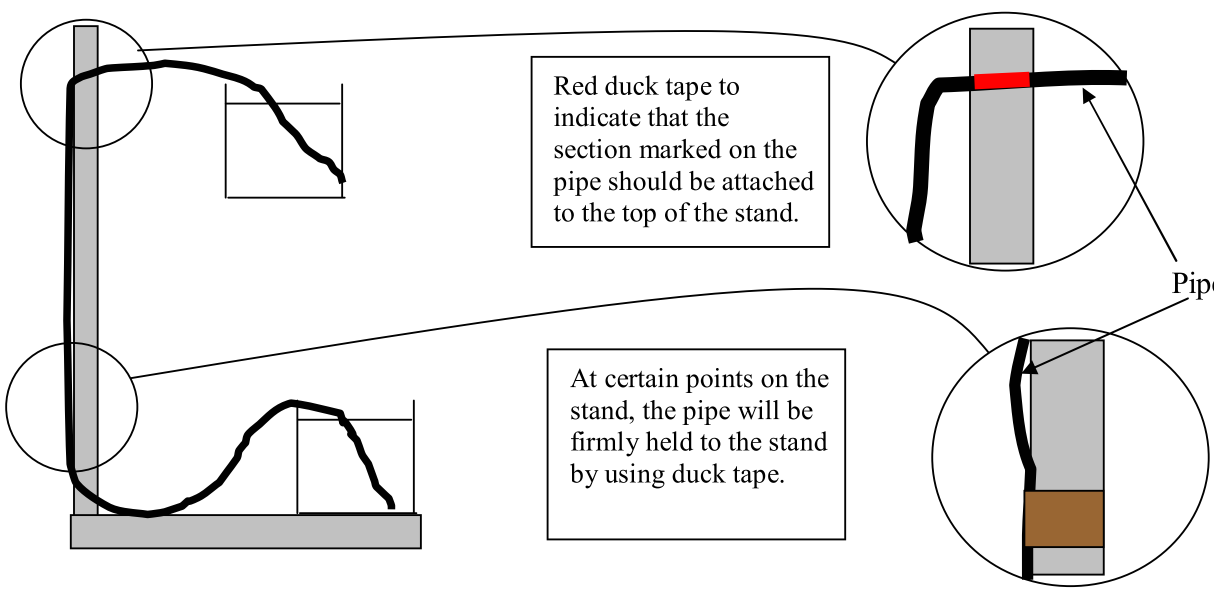


Testing with pipe of diameter X mm



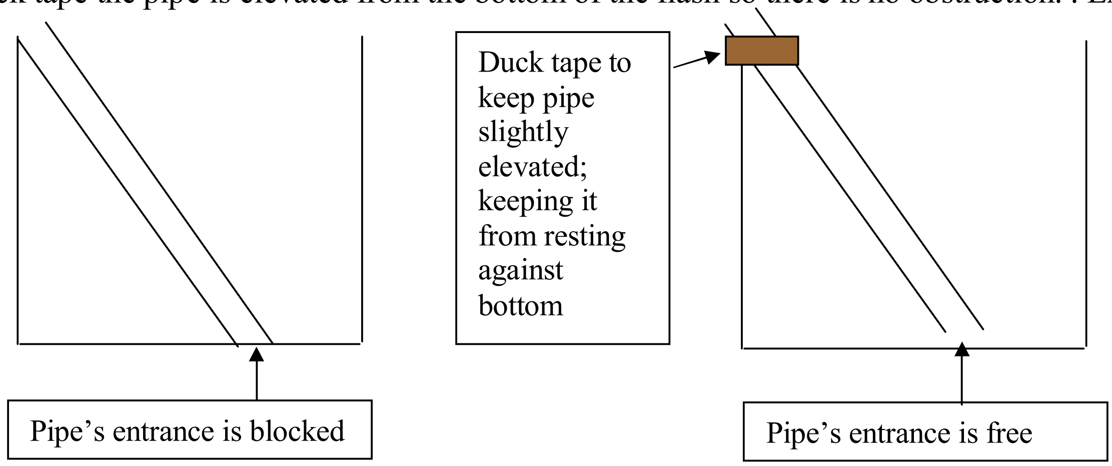
Testing with pipe of diameter Y mm

Although the pipes are of exact same length the path the water has to follow is not the same. Since the siphon's performance relies heavily on the pipe's position it is crucial that the pipes follow the exact same path. To do this I will be putting marks on the pipes by using red duck type to indicate certain points on the pipe in relation to the stand. Ex.



Another factor that seemed to cause a slight unfairness in the test was the fact that the flow rate was not constant during the displacement of the liquid. This occurred towards the end of the liquid displacement. As the water emptied out of the top flash the siphon found it hard to move all the water out of the flask due to air getting inside the tube. To solve this problem more then 300ml of liquid will be put in the top flask and so you only need to stop the timer when 300ml is in the secondary flask and not by letting all the water empty from the first. This is too make sure that the pipe has a plenty volume of water throughout the displacement.

The last problem I noticed was that the pipe in the top beaker rested against the bottom of the flask. This obstructed the pipe's hole which affects the siphon's performance. By using a piece of duck tape the pipe is elevated from the bottom of the flash so there is no obstruction. . Ex.



II. The effect of Temperature on flow rate:

Factors to keep constant:

Pipe Diameter:	7 mm
Vertical Height:	0.50 m
Liquid Volume:	300 ml
Liquid used:	Tap water

Results:

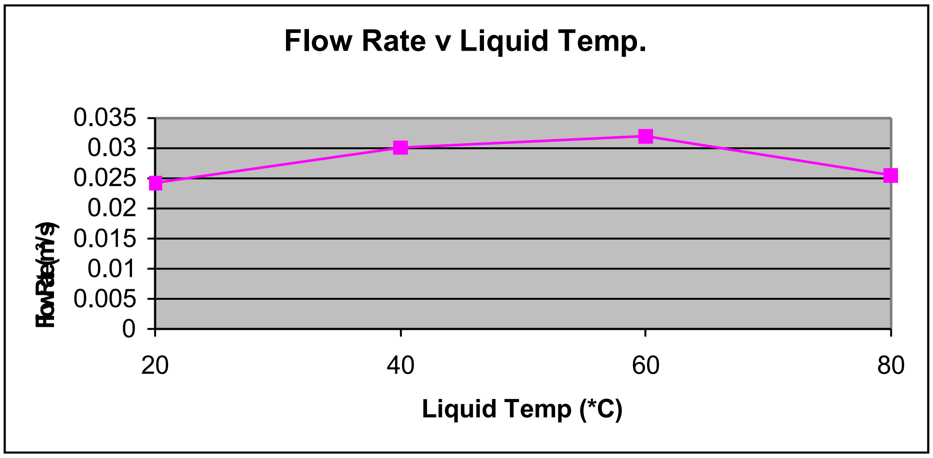
Liquid Temperature	**Run #1**	**Run #2**	**Run #3**
20*C	12.08 s	12.95 s	12.10 s
40*C	9.78 s	10.02s	10.06 s
60*C	10.09 s	8.79 s	9.10 s
80*C	11.06 s	12.24 s	12.02 s

Average Readings:

Liquid Temp.	**Average Reading**
20*C	12.38 s
40*C	9.95 s
60*C	9.36 s
80*C	11.77 s

Flow Rate:

Liquid Temp.	**Flow rate**
20*C	0.02423 m^3 / s
40*C	0.03015 m^3 / s
60*C	0.03205 m^3 / s
80*C	0.02549 m^3 / s



I was not at all happy with the results obtained for temperature. As clearly shown on the graph the flow rate was everywhere. It didn't really show any increase or decrease in flow rate at any particular pattern.

An explanation for no significant change in flow rate is due to the fact that if temperature doesn't physically change the liquid's viscosity temperature does not actually affect the rate of siphoning. The water's viscosity change is so minimal that it doesn't flow any quicker; the way Stokes law defines.

One other point that should not be underestimated is that the investigation of the affect of temperature on liquid flow was carried out on two consecutive days. The difference in atmospheric pressure could explain the slight difference in my results. Another factor could have been that the pipe route was not exactly the same on the two days. I have already explained how to solve this problem earlier in this report.

Another problem, which I noticed was that the blue-tack holding the pipe in place, did not hold properly as higher temperatures were used. Holding the pipe in place using duck tape will solve this.

III. The effect of Viscosity on flow rate:

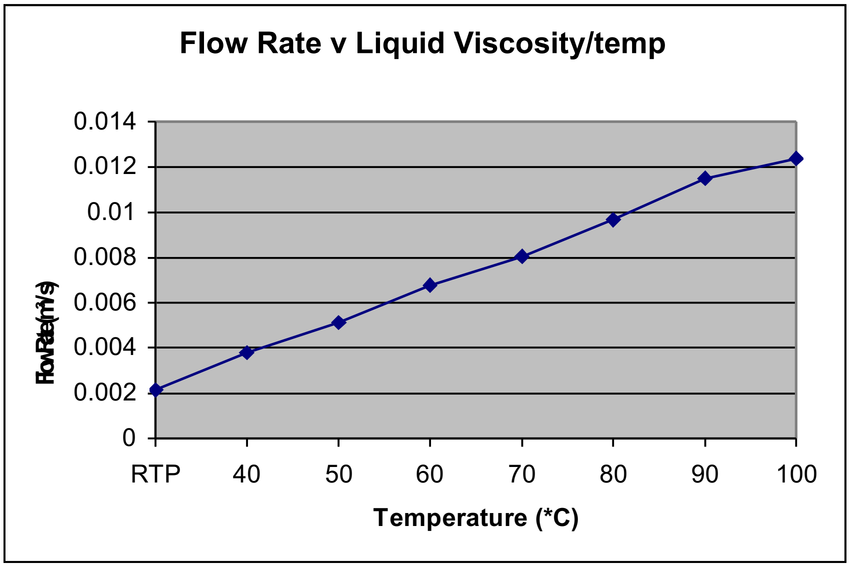
Factors to keep constant:

Pipe Diameter:	7 mm
Vertical Height:	0.50 m
Liquid Volume:	300 ml
Liquid used:	Olive Oil

Olive Oil's Viscosity (η) at RTP is **8.4×10^{-2} N s m^{-2}**

Results:

Liquid Temperature	Run #1	Liquid Temperature	Liquid Flow
RTP	139.00s	RTP	0.00216 m^3 / s
40*C	79.00s	40*C	0.00380 m^3 / s
50*C	58.39s	50*C	0.00514 m^3 / s
60*C	44.24s	60*C	0.00678 m^3 / s
70*C	37.31s	70*C	0.00804 m^3 / s
80*C	31.00s	80*C	0.00968 m^3 / s
90*C	25.12s	90*C	0.01149 m^3 / s
100*C	22.09s	100*C	0.01238 m^3 / s



We can clearly see here that a liquid such as olive oil, which undergoes a huge viscosity change with temperature, is directly proportional to the flow rate. For the final test I will be finding the actual viscosity co-efficient as the temperature changes but this is only meant to give us a rough guide to what to expect in the actual test.

In my initial plan I said I would be heating the liquid by putting the flash in a hot water bath. I've decided against this just due to the fact that the temperatures I have to attain for the liquid is rather high and would be too time consuming to reach such high temperatures using a hot water bath. So as an alternative I've opted to simple heat the liquid by heating it on a Bunsen burner. This way I can easily obtained the desired temperature in a relatively short period of time.

It goes without saying…Oil is very messy so I have to keep an eye on spillages!

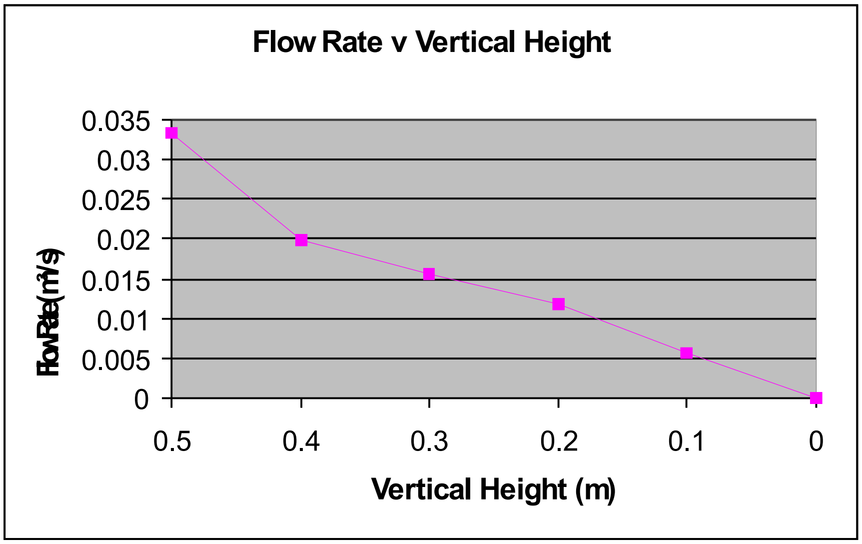
IV. The effect of Vertical Height on flow rate:

Factors to keep constant:

Pipe Diameter:	7 mm
Liquid Temperature	20*C
Liquid Volume:	300 ml
Liquid used:	Tap Water

Results:

Vertical Height	**Run #1**	**Vertical Height**	**Liquid Flow**
0.5 m	9.00 s	0.5 m	0.03333 m^3 / s
0.4 m	15.14 s	0.4 m	0.01982 m^3 / s
0.3 m	19.19 s	0.3 m	0.01563 m^3 / s
0.2 m	25.53 s	0.2 m	0.01175 m^3 / s
0.1 m	52 s	0.1 m	0.00577 m^3 / s
0.0 m	---	0.0 m	0.00000 m^3 / s



We can clearly see that that Flow rate is proportional to vertical height. In fact the vertical height is one of the biggest factors affecting flow rate. When the vertical height was dropped to 0 m the flow rate was so small that it can be said to be negligible but as vertical height was increased so did the flow rate.

There is nothing which I want to change in respect to this part of the investigation. Accuracy with measuring height could be improved but apart from that there will be no alterations carried out to the apparatus.

- **Final Results:**

I. The effect of Pipe Diameter on flow rate:

Factors to keep constant:

Liquid Temperature:	20*C
Vertical Height:	0.50 m
Liquid Volume:	300 ml
Liquid used:	Tap water

Results:

Pipe Diameter	Run #1	Run #2	Run #3
3 mm	90.92 s	91.06 s	90.72 s
5 mm	20.51 s	21.39s	21.25 s
7 mm	8.94 s	9.00 s	8.87 s
9 mm	4.01 s	3.93 s	4.07 s

Average readings:

Pipe Diameter	Average Reading
3 mm	90.09 s
5 mm	21.05 s
7 mm	8.94 s
9 mm	4.00 s

Flow Rate:

Pipe Diameter	Flow rate
3 mm	0.00333 m^3 / s
5 mm	0.01425 m^3 / s
7 mm	0.03356 m^3 / s
9 mm	0.07500 m^3 / s