International Baccalaureate

Extended essay cover

SAMPLE B

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: HOW DOES THE TEMPERATURE OF A BATTERY AFFECT THE POWER THE BATTERY IS ABLE TO GIVE.

Candidate's declaration

If this declaration is not signed by the candidate the extended essay will not be assessed.

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: ______________ Date: 25/2/09

IB Cardiff use only: A: 44386 B: ______

International Baccalaureate, Peterson House,
Malthouse Avenue, Cardiff Gate, Cardiff CF23 8GL, Wales, United Kingdom

Supervisor's report

The supervisor must complete the report below and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator. The supervisor must sign this report; otherwise the extended essay will not be assessed and may be returned to the school.

Name of supervisor (CAPITAL letters) ?

Comments

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.

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: 11/3/09

His investigation was on how the temperature of a battery affects its power. This is a reasonably well researched and presented piece of work, although the results and the outcomes are not as ambitious as expected. I feel the measurement technique is not sensitive enough to measure minute differences in the voltage. After persevering with the project the student did not find sufficient evidence to support his theory. Nevertheless he tried his best to present his findings in a reasonable manner.

Essay Supervisor

Assessment form (for examiner use only)

Candidate session number	0	0	

Achievement level

Assessment criteria

	First examiner	maximum	Second examiner
A research question	1	2	2
B introduction	1	2	1
C investigation	1	4	1
D knowledge and understanding	0	4	1
E reasoned argument	1	4	1
F analysis and evaluation just!	1	4	1
G use of subject language	1	4	1
H conclusion not sufficient	0	2	0
I formal presentation	3	4	2
J abstract	1	2	1
K holistic judgment	0	4	0
Total out of 36	10		11

Name of first examiner: ______________________ Examiner number: __________
(CAPITAL letters)

Name of second examiner: ______________________ Examiner number: __________
(CAPITAL letters)

Title Page

Extended Essay

See abstract

How does the temperature of the molecules within a battery affect the power the battery is able to give out?

RQ

V. poor grasp of the simplest possible circuit. He measures "EMF" of cells immersed in water – the small changes in "EMF" are, no doubt, due to the changing conductivity of water & so the terminal p.d. that decreases a little. He mentions power & current but does not attempt to measure either (no ammeter used). Most comments show almost no understanding of this topic. RQ is rather weak and the significance of it is not demonstrated.

By Ore Ladele

Abstract

In this research task I investigated how the external temperature surrounding a battery will affect the power the battery is able to give out. I carefully planned and implemented the experiment following safety regulations and keeping the test fair.

In the project I placed different types of batteries in a hot water bath and using multi-meters and a kettle I was able to record the temperature of the water, voltage given off by the battery and current running through the circuit. Using the equation P= IV I was also able to find the total power given off by the battery at different temperatures.

From my results I was able to see that the external temperature will affect normal domestic batteries but not a long lasting fire alarm battery. This was clear to see from my results and the graphs as the potential difference given off by a normal battery was quickly reduced as the temperature of the water surrounding it increased. The fire alarm battery however didn't change voltage out regardless of the temperature

I put this down to the fact that normal domestic batteries are made to work in the household for a short period of time and are usually kept at around a relatively small range of temperatures. The fire alarm battery however is made to last for several years and with this in mind it has to endure the cold temperatures of winter and the hot temperatures during the summers and therefore can withstand these temperatures changes to give off a constant power.

Contents Page

Introduction

In this essay, I will be exploring the thesis of how by changing the external temperature surrounding a battery, the maximum power output may or may not be affected as a direct result. I have chosen this particular topic for my essay, as I am particularly interested in the conditions that determine whether objects work at their optimum or minimum. In this case, I have chosen to research the battery, as it is a common household appliance that is used to fulfil the basic service of providing electrical energy across the world.

In order to investigate how the temperature will affect the power that is output by the battery, I intend to change the surrounding thermal conditions of the battery and monitor how the voltage varies, assuming that the voltage changes as a result. I expect the quantity of voltage to change because as the temperature increases or decreases, the kinetic energy of the molecules within the battery also increases or decrease. This means that the electrons that are drawn out to provide the current collide with different frequencies, thus altering the internal resistance of the battery at different temperatures.

Furthermore, I intend to keep the current flowing around the circuit, which will be connected in series each time, constant regardless of the temperature. As a result of this, I can assume from the equation:

Potential Difference (V) = Electrical Current (I) x Resistance (R),

that the voltage fluctuates due to the changes in the battery's internal resistance. Moreover, from this I will be able to deduce the affect of the batteries power output as:

Electrical Power (W) = Potential Difference (V) x Electrical Current (I),

and if the voltage changes then so also most the total power output.

From this experiment, I will be able to deduce the optimum temperature for the battery to operate at and I will be able to draw conclusions as to the reasoning behind this. At this moment in time, I predict that most batteries are likely to be tailored to perform at their best in normal room temperatures, and therefore if they are heated up excessively then they will begin to give out less power. I am predicting this because batteries are used in everyday household appliances and we are told to keep them stored at room temperature and pressure (RTP).

During my investigation I plan to use a range of different type of batteries with different voltages and with difference purposes to see how each of them react to the changes in temperature. This is to ensure that I do not make generalisations for all types of battery, but I am able to reason well according to each specific type.

During my experiment, I know that I will have limitations, which may prevent me from being able to collect accurate data. For example, I will not be able to be absolutely sure that the time I have left the battery in the water for long enough for the molecules to react to the change in temperature. I also know that I will be unable to ensure that I control the temperature to produce fair and regular intervals when increasing the temperature of the water. I do feel however that this is a negligible factor when collecting the data for the experiment and it should not affect the outcome of the results.

physics context not clear, not fully exact, confusing;
worthiness: sort of shown;

=> intro: 1/2

Main Body

Prediction

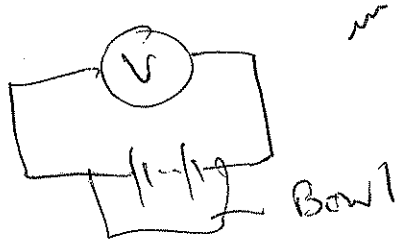
I predict that my experiment will prove that as the temperature of the battery increases, the maximum power output by the battery decreases. I also predict that the optimum temperature for the battery's performance is somewhere around room temperature, as batteries spend most of their shell life operating at room temperature.

Equipment

Two Crocodile Clips
Two Wires
Multimeter
9V Battery
AA Battery
Thermometer
AAA Battery
6V Fire Alarm Battery
Kettle
Bowl
Stopwatch

Variables

Dependant: Power, Type of circuit.
Independent: Temperature of water, Types of Battery.
Controlled: Current.



Safety Measures

- Lab Goggles will be worn at all time to protect eyes from hot water if it splashes.
- Current must be kept low to ensure we do no overheat anything in the circuit and blow it

Method

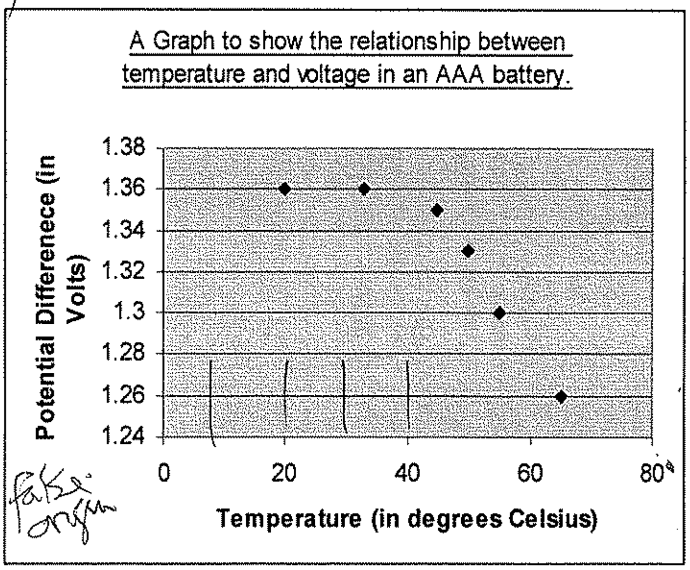
1. I set up the experiment as shown in diagram 1:1[1].
2. I put the battery into a bowl of water while using a thermometer to calculate the temperature.
3. I left it in there for 2 minutes to allow the molecules inside the battery to experience and subsequently react to the temperature change.
4. I then recorded the voltage and then changed the temperature of the water by adding boiling water to the bowl.
5. I continued with the process and continued to record the voltages at other temperatures to see if there was any change in the voltage output by the battery, as a direct result of the changes in temperature.
6. I repeated my experiment to obtain three different readings each time and recorded my average results. These were then plotted on a graph.

Using the formula: Electrical Power (W) = Potential Difference (V) x Electrical Current (I), I believe that the voltage is directly proportional to the power as a result of the current remaining constant.

Results

The AAA Battery

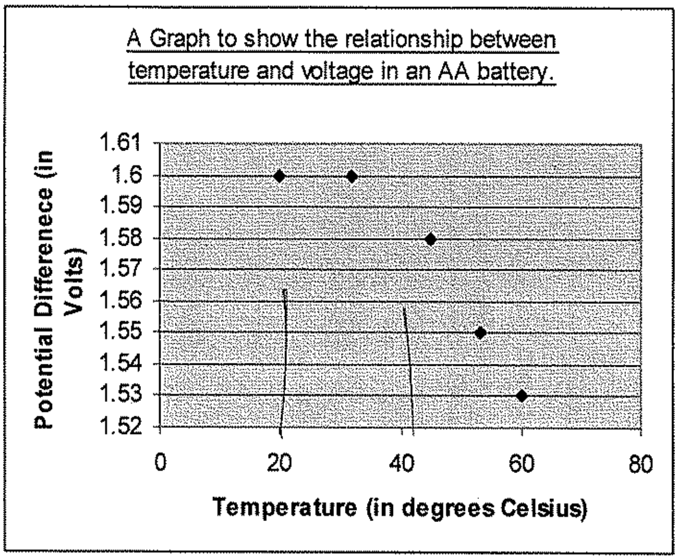
BATTERY: AAA	
Temp. (°C)	P.D. (Volts)
+20	+1.36
+33	+1.36
+45	+1.35
+50	+1.33
+55	+1.30
+65	+1.26



[1] See diagram in Appendix

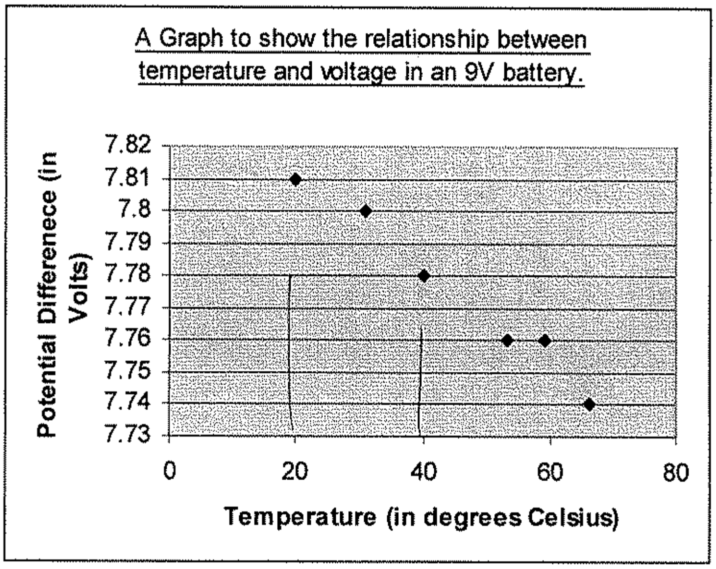
The AA Battery

BATTERY: AA	
Temp. (°C)	P.D. (Volts)
+20	+1.60
+32	+1.60
+45	+1.58
+53	+1.55
+60	+1.53



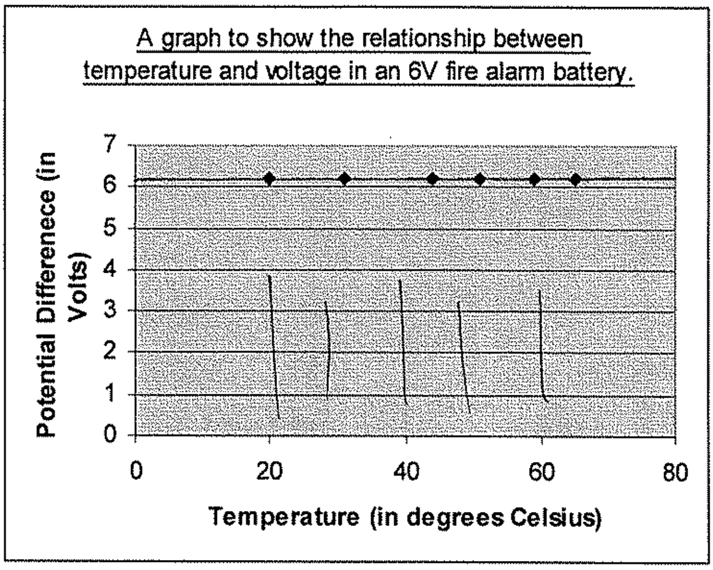
The 9V Battery

BATTERY: 9V	
Temp. (°C)	P.D. (Volts)
+20	+7.81
+33	+7.80
+45	+7.78
+50	+7.76
+55	+7.76
+65	+7.74



The 6V Fire Alarm Battery

BATTERY: 6V FIRE ALARM	
Temp. (°C)	**P.D. (Volts)**
+20	+6.22
+31	+6.22
+44	+6.22
+51	+6.22
+59	+6.22
+65	+6.22



Interpretation and Justification of Results

Interpretation of Results

From these results, it is fair to conclude that as the temperature increased, the maximum power output of the AAA, AA and 9V batteries decreased. Furthermore, the power output of these batteries all decreased in an extremely similar fashion by similar amounts each time. However, the 6V fire alarm battery gave out the same power throughout the experiment. The optimum performance of the AAA, AA and 9V batteries was at 20°C, whereas the 6V fire alarm battery maintained a constant performance level.

How a Battery Works

Batteries convert chemical energy into electrical energy. They consist of one or more voltaic cells, which in turn consist of two half-cells that are connected in series by a conductive electrolyte. One half-cell is the positive electrode while he other is the negative electrode. The current that flows in a circuit is passed through the electrolyte, as this is an ionic substance.

The value of the resistance of an electrolyte decreases as the temperature of the electrolyte increases. This is because the ions in an electrolyte gain kinetic energy as the temperature increases, as the particles as more active it is easier for electricity to flow. This means that as the temperature of the electrolyte increases, its conductivity also increases. I found out that:

$$\text{Conductivity}(\mathbf{k}) = \frac{\text{Electric current } (\mathbf{I})}{\text{Voltage } (\mathbf{E})} \times \frac{\text{length } (\mathbf{L})}{\text{Area } (\mathbf{S})}$$

Therefore, if all the factors in the equation, except for the conductivity and voltage, are kept constant, we can see that for the conductivity of a material to increase, the voltage across the material must decrease. Furthermore, I know from the equation: Potential Difference (V) = Electrical Current (I) x Resistance (R), that if the voltage decreases at a constant current, the reasoning behind this must be that the resistance of the material must have also decreased.

I can, therefore, deduce from all this from all this information that as the temperature of the electrolyte in a battery increases, its resistance of the substance decrease and so a lesser voltage is needed to push the current around the circuit.

Justification of Results

I believe that the reason for the AAA, AA and 9V batteries showing the decrease in power is that these are domestic use batteries, which are tailored to operate within the home at room temperature, over a relatively short period of time. For example, some common uses of these batteries would include household appliances and children's toys. In domestic use batteries, their insulating properties are quite poor start to deteriorate with a rise in temperature and so as I increased the temperature surrounding the battery, the temperature of the electrolyte would also increase. As I previously explained, when the temperature of an electrolyte increases its resistance decreases and so a lesser voltage is needed to push the current around the circuit. Following on from this, using the equation: Electrical Power (W) = Potential Difference (V) x Electrical Current, I can surmise that as the voltage decrease across the circuit, the power output by the battery must also decease, considering that the current remains constant. Therefore, my experiment shows that in AAA, AA and 9V batteries the maximum power output decrease as the temperature increases. same wrong argument repeated again

The maximum power output of the 6V fire alarm battery on the other hand, remained constant. This type of battery are tailored to be used in fire alarms for up to five years, as this therefore would mean that it must be able to withstand the various weather changes as well as high temperatures when there is a fire. In my opinion, the 6V fire alarm must have better insulating properties than the other batteries as the battery must be able to withstand the heat of fires to power the alarms. Therefore, an increase ? in temperature would not mean an increase in the temperature of the electrolyte within the battery. As a result, the conductivity of the electrolyte would remain the same throughout the experiment, and following on from this, there would be no change in the electrolyte's resistance. This is why it has been able to maintain a constant voltage throughout the experiment. Therefore, the battery was able to maintain a constant power output throughout the experiment. However, I believe that if the temperature were increased to the extent so as to exceed and overcome the insulating properties of the 6V fire alarm battery, then the maximum power output would decrease in a similar fashion to the AAA, AA and 9V batteries for the same reasons. (nothing really significant per se)

- the physico-chem. of the battery is actually not known / not understood / investigated;
- very superficial / elementary knowledge;
- no understanding of the circuitry;
- procedure followed confused and confusing;
- language: concepts confused
- argument: v. limited; basically unfounded;

Conclusion

From my results I can conclude that if you change the external conditions effecting domestic use batteries then you will be able to control the amount of power the battery will give to a device. From my graphs it is also fair to assume there is a strong relationship between the temperature of the external conditions of the battery and the power it gives out if the battery is a normal domestic battery. The 6V fire alarm battery, on the other hand, doesn't follow the same principle because of the purpose it was tailored for. I have concluded that this is because of the insulation of each type of battery it would seem that fire alarm batteries are better insulated and therefore last longer and a lot more expensive whereas normal domestic batteries aren't insulated because they are used frequently and disposed of.

Others however have tried to argue that this is not the case. For example on the Duracell website it states "The reliable energy source of Duracell Plus AA/AAA now lasts even longer than before."[3] Now in my experiment its shows that batteries are not a reliable source of energy if they are taken out of their range of comfort but batteries manufacturers will tell customers that their product is great in all conditions just to sell. It also says "Duracell has a freshness guarantee of 7 years and guarantees performance during that time. As there are thousands of various devices and usage there is no one performance life expectancy that is given."[4] Now this states that the Duracell batteries will be able to withstand varying conditions over the 7 years of its guaranteed freshness, however I feel this is a false promise because the experiment has proven that batteries made for domestic use are unable to withstand these conditions.

[3] http://www.duracell.com/uk/products-detail-plus.aspx site checked: 9.45 21st January 2009
[4] http://www.duracell.com/uk/faq.aspx#alkaline site checked 9.51 21st January 2009

Evaluation

Suitability of Method

In my opinion, my method was very suitable for this experiment. I believe this because the repeated results were, overall, very close together. Furthermore, I believe that my results as they proved my prediction by displaying the same pattern. One criticism I have of my method is that as I was unable to prevent energy escaping into the environment as I did the experiment this would have therefore meant I would not have been able to control the true temperature of the molecules within the battery and as a result not be able to draw definite conclusions on how much the potential difference would drop depending on how many degrees the external temperature was from room temperature.

Limitations of Method

As I previously explained in my introduction, I experienced some limitations in my experiment that prevented me from being able to collect accurate data. I was not able to be sure that the time that I left the battery in the water for was long enough for the molecules to react to the change in temperature, however, I did leave all the batteries in the water for an equal amount of time each so that all the batteries would be affected fairly.

I also was unable to control the temperature to produce fair and regular intervals when increasing the temperature of the water. To improve this limitation I may have looked into controlling the temperature of the surroundings so that the amount of energy lost to the environment was minimised. For example I could have put the experiment into an air tight container to prevent convection currents which would cause energy to be lost a slower rate. I do feel however, that both these issues are negligible factors when collecting the data for the experiment and that they did not affect the outcome of the results.

Reliability

I also think that, overall, my experiment was quite reliable. The close results among my repeats show that if somebody else were to repeat the experiment in the same manner they would obtain similar results to my own. Furthermore, the repeat in the pattern displayed amongst some of my results showed that is extremely likely that the relationship I was trying to prove existed. The only problem I would have had with my results would have been in the amount of error each of the instruments I used would have had. For example the thermometer I used only measured in one interval which would have meant I had a ±0.5 error for that instrument. My multimeter however was very accurate and measures to 0.01 of a volt which would have meant that my error would have been ±0.005 for that instrument

Assessing the Validity of My Conclusions

I think that my conclusions are valid in terms relationship they show. Having judged the reliability and accuracy of my result, and assessed the limitations of my method, I feel that the overall uncertainties in my experiment are not particularly significant in the validity of the conclusions that I have drawn. Therefore, I believe that as the internal temperature of a battery increases due to an increase in temperature of its surroundings, the maximum power output of the battery decreases.

Furthering my Investigation

In the future I think that to further this investigation I should research into whether or not temperature is the only thing that will affect the power given out by a battery. For example I could research into how gravity may play a roll in how a battery performs and whether or not the power given off is affected if the battery is at a high or low altitude or is stationary or falling. I could also simply further this investigation by looking into how if I change the temperature in the other direction the power given out by the battery will change. Will it increase as the temperature continues giving a straight line graph or will it decreases and show a maximum point for each battery to be stored at. I feel that the 6V fire alarm battery however will be unaffected by the temperature change even if it was reduced into the minus'.

References and Bibliography

- access dates missing;
- very limited;
- no books/articles re relevant physico-chemistry

i. http://en.wikipedia.org/wiki/Battery_(electricity)

ii. http://www.jp.horiba.com/index_e.htm

iii. http://books.google.co.uk/books?id=A4FJY_u9FBQC&pg=PA48&lpg=PA48&dq=temperature+increases+resistance+electrolyte+decreases&source=web&ots=mkhXrrdjir&sig=Zwkxh5Yhw2T4F26MdrmgtUDJR7w&hl=en&sa=X&oi=book_result&resnum=10&ct=result

iv. http://www.mpoweruk.com/thermal.htm

v. http://www.duracell.com/uk/

only complete citation given (on p 12)

** - most references not cited in core of essay

- the topic involves physico-chemistry, a complex domain; the domain was superficially surveyed;
- basic circuit physics not brought up completely*, and some key questions remain: how the battery was made "water tight" and how contacts were made so to avoid a short-circuit;
- "power" part of the RQ ... no power calculated ..

(* eg $V_T = \varepsilon - rI$)

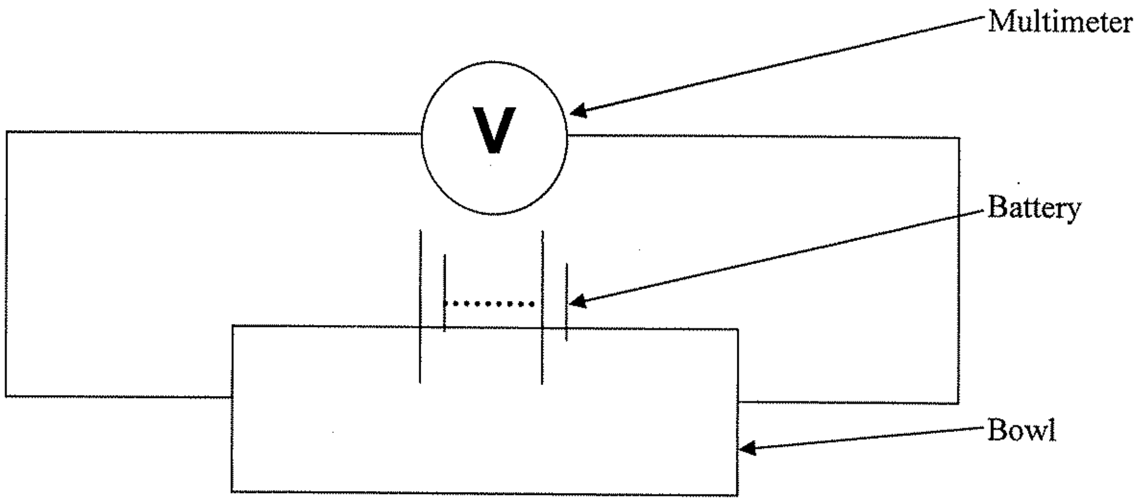
- not a good choice of topic for theoretical & practical reasons; argument re makers of battery "not physics per se";

- presentation: bibliography not following standards; tables, graphs and equations not numbered for reference in the text; no circuit illustrating all relevant variables; incomplete graphs & tables; style not ideal for an extended essay;

Appendix

how do you get Emf? terminal voltage? and current?

1.



resistance of voltmeter?

should be on page 6