4th International Junior Science Olympiad

Practical Examination

December 08, 2007

Important Remarks

1. While you are in the laboratory, you should wear safety spectacles at all times.
2. Eating of any kind of food is strictly prohibited in the laboratory. If necessary you may ask Lab Assistant and take a snack break nearby the laboratory.
3. The safety showers are located inside the bathroom on both side of the stage.
4. Participants are expected to work safely, to behave socially and to keep equipment and work environment clean. When carrying out discussions with your teammates, keep your voice low.
5. Do not leave the examination laboratory until you have permission to do so. Ask Lab Assistant if you need to use the bathroom.
6. **Work may only begin when the start signal is given.**
7. You have **4.5 hours** (including extra 30 min reading time) to complete the experimental task, and record your results on the answer sheets. There will be a pre-warning 30 minutes before the end of your time. You must stop your work immediately after the stop command is given. A delay in doing this by 5 minutes will lead to zero points for the task.
8. Be sure that your team has a complete set of the experimental examination (3 copies) and the answer sheets (4 copies). **Only one copy (light yellow paper) of the answer sheets should be submitted for marking.**
9. **Use only the pen and calculator provided.**
10. Team code and student codes must be written on every page of the final answer sheets. **Each team member must sign on the front page of the final answer sheets.**
11. All results must be written in the designated boxes on the answer sheets. Data written elsewhere will not be graded.
12. After completing the task, put all the equipments back to its original place and discard all solutions in the beaker labeled “Waste”.
13. **After the stop command is given, put ONLY the final answer sheets (one copy) on top of the envelope on the desk. Wait for the Lab Assistant to check and collect it. You can take the other papers with you.**

A. Introduction

Energy is essential in our everyday life. Electricity is one of the forms of energy that is easily obtained in modern society. To produce and convert electricity efficiently is one of the most important issues in the 21st century. In this task, you will construct a chemical battery, find out how electrolytes affect the current, and assess how well (or poorly) natural products conduct electricity. Electricity can be utilized to promote light, heat, and chemical reactions. You will connect commercial batteries to a system to initiate electrolysis and initiate a chemical process. Heat is an unwanted byproduct upon the conversion of electricity to light. You will determine the temperature of an incandescent lamp.

B. Objectives (They are not necessarily to be solved in sequence.)

I. To study the characteristics of a fruit battery and to determine the factors that influence the efficiency of the fruit battery.

II. To observe the starch particles in potato and to determine how chemical reagents affect them.

III. To assess the relationship between the concentration of an electrolyte and the conductivity of an electrolysis cell. To determine the concentration of an electrolyte solution from the concentration-conductivity relationship and by acid-base titration.

IV. To investigate the thermal and energy transfer properties of the tungsten filament in an incandescent lamp.

C. Apparatus and Materials

Part I: Fruit Battery

Materials	Quantity	Materials	Quantity
Lime	6	Petri-dish	3
Multimeter (in common basket)	1	Ruler (in common basket)	1
Connecting wire	6	Scissor	1
Metal plate	1 set (A, B, C, D)	Binder clips	6
LED device	1	Knife (For Part I & II)	1
Wash bottle 500 mL (in common basket)	1	Paper towel (in common basket)	1
Latex glove (wear all time for Part I, and III)	1 (more are available)	Towel (in common basket)	1

Part II: Starch Granules

Materials	Quantity	Materials	Quantity
Potato	1	Cover slip, Slide	1 set
Microscope	1 set	Iodine solution (1%)	1
Knife (in Part I basket)	1	Reagents (labeled with A, B & C)	3

Part III: Conductivity of electrolyte solution

Chemicals	Quantity	Chemicals	Quantity
0.5 $mol \cdot L^{-1}$ $NaOH_{(aq)}$	100 mL	0.25 $mol \cdot L^{-1}$ $HCl_{(aq)}$	100 mL
A solution of $NaOH_{(aq)}$ of unknown concentration	100 mL	Indicator	1 mL

Apparatus	Quantity	Apparatus	Quantity
Multimeter (in common basket)	1	Burette holder and rack	1
Connecting wire	4	Burette 50 mL	1
Battery set (3V, for this Part only)	1	Funnel	1
Pt electrode	2	Erlenmeyer flask 125 mL	3
Plastic test box	2	Test tube	2
Beaker 600 mL	1	Graduated cylinder 50 mL	1
400 mL	1	10 mL	1
100 mL	4	Dropper	10
Forceps	1	Label	1
Latex glove (in common basket)	1	Towel (in common basket)	1
“Waste” beaker 1000 mL (in common basket)	1	Wash bottle 500 mL (in common basket)	1

*More distilled water are available. Ask Lab Assistant.

*You should wear gloves at all time. In case of skin contact with acid or base, wash with distilled water immediately.

*All glass wares provided are clean, and there is no need to wash before experiments. However, if necessary, you may clean them with a wash bottle and transfer the waste to a beaker labeled “Waste”.

*Keep the battery box on the “off” position when not in use as shown below.

off

on

Part IV: Energy Transfer Associated with an Incandescent Lamp:

Apparatus	Quantity	Photo #
Battery set (6V, for this Part only)	1	Photo IV-1
Light Bulb	1	Photo IV-2
Resistors	9	Photo IV-3
Connecting wire	6	Photo IV-4
Thermometer (fixed on the partition. Read only, don't touch)	1	Photo IV-5
Multimeter (in common basket)	2	

Photo IV-1. Battery set: The voltage is 6 V. There are two leads, positive and negative, colored red and black, respectively. The battery set will be represented by the circuit symbol .

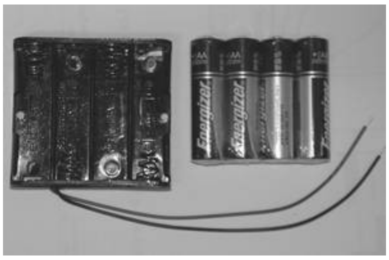
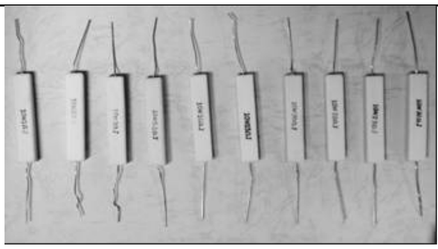


Photo IV-2. Incandescent light bulb set. This light bulb set has two leads for connection. The light bulb set will be represented by the circuit symbol .

Photo IV-3. Resistors. Each is labeled with power rating (10W), Resistance (~ Ω), and Type (J). The resistor will be represented by the circuit symbol .



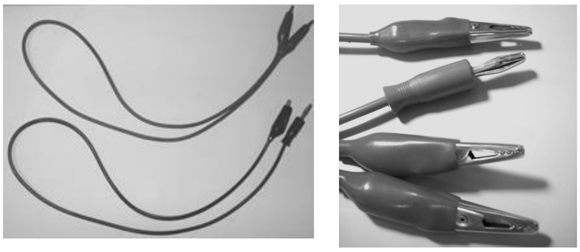
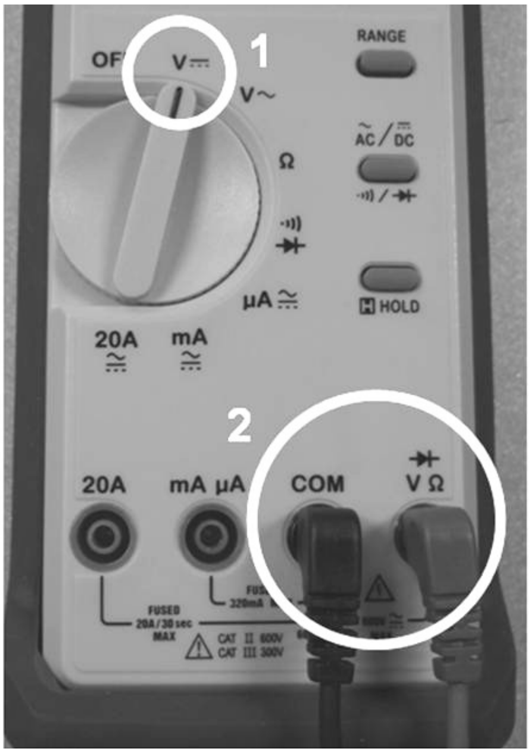


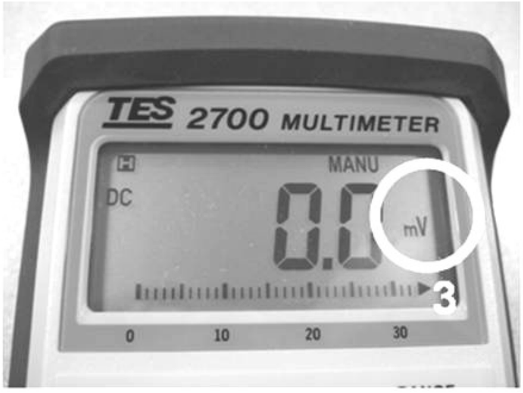
Photo IV-4. Connecting wires. Two types of wires are provided: alligator- alligator and alligator-banana.

Photo IV-5. Thermometer: The thermometer shows Celsius reading. If Fahrenheit reading is shown, ask Lab Assistance. Read the temperature only, do not touch.

Wire connection and dial setting for using Multimeter

Measure Voltage:

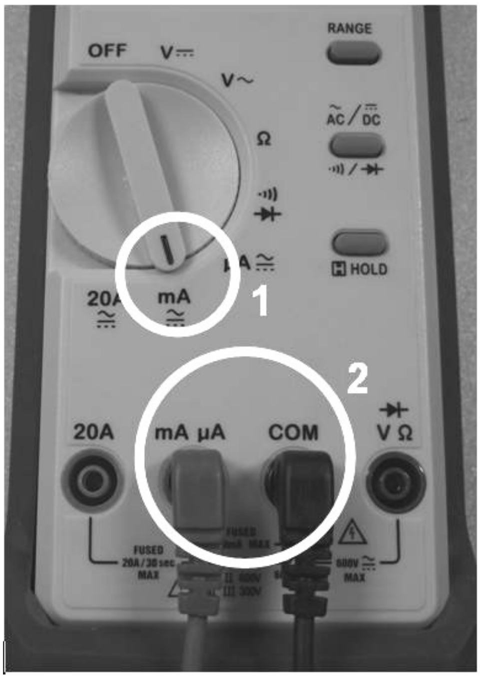




1. Voltage (Direct current)
2. COM (Black);

   V (Red)
3. Voltage unit (V or mV)

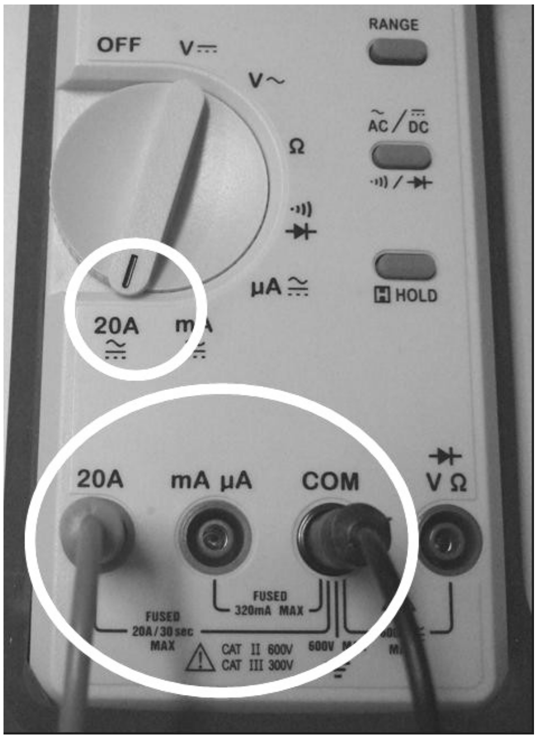
Measure current: There are three ranges setting for measuring current. In Part I and III you will use mA and μA ranges. The wire connection is the same for both mA and μA range measurements, but the dial should turn to the appropriate place.



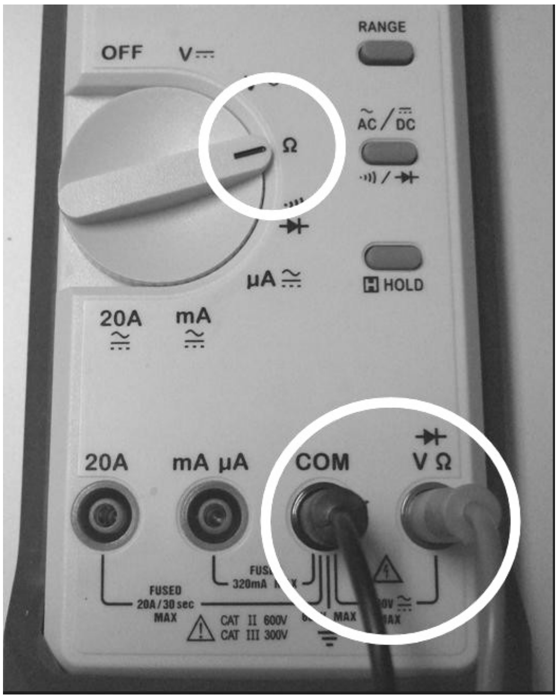
1. Current
2. COM (Black)

   mA or μA (Red)
3. Current unit (mA)
4. Direct current

In Part IV, you have to use 20 A setting for measuring current. **Incorrect dial setting and wiring of multimeter will cause damages and no points will be given.**



Measure Resistance: Ohm-meter can only be used in the open circuit condition.



D. Experiments and Questions

Part I: Fruit Battery

Batteries contain two electrodes which typically consist of different kinds of metals, and are filled with electrolyte to produce electricity from the chemical reactions between the electrodes and the electrolyte. Instead of chemical batteries, fruits can also be utilized to generate electricity. Fruits contain lots of juice (electrolyte) which could ionize electrodes, the ionization tendency of which depends on the kind of metals and fruits. Questions I-1~I-3 are assigned to assist you to determine the characteristics of the fruit battery.

Question I-1: Determine how the electrodes affect the fruit battery

Procedures:

1. Use lime to complete this experiment. The thickness of the lime between the two electrodes should be limited to no more than 1 cm as shown in Figure I-1.

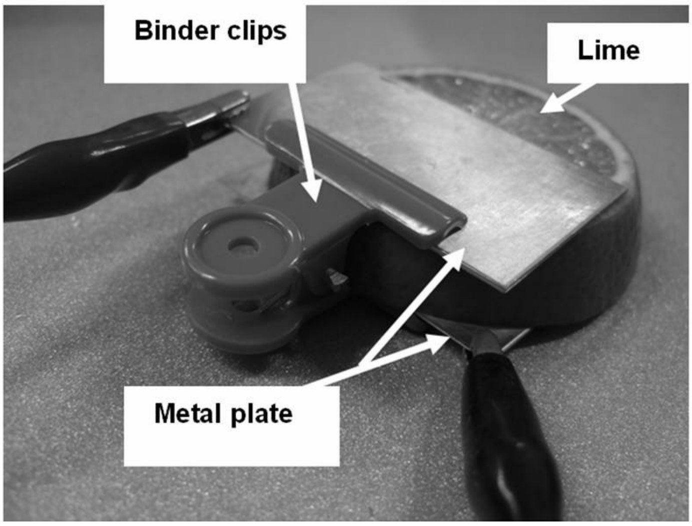


Figure I-1

2. Use metal B as the positive electrode (+) and metal A, C and D as the negative electrode (-) in different setups, measure the voltage generated by these fruit batteries. Wire connections are shown in Figure I-2.

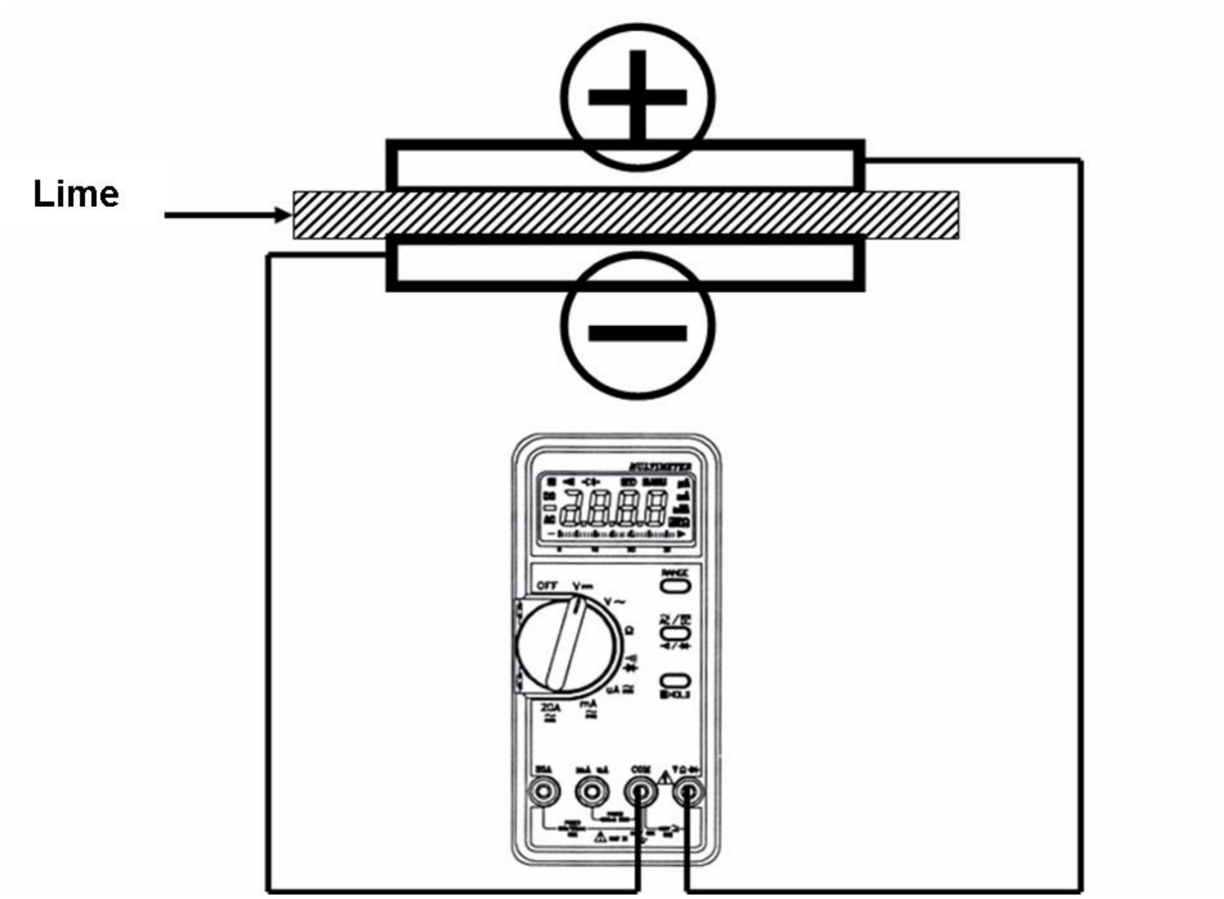


Figure I-2

3. According to your results, answer **Question I-1-a** and **I-1-b.**

I-1-a. Use metal B as the positive electrode, which metal on the negative electrode gives the highest voltage.

I-1-b. According to your observations, answer the following questions.

i. If metal D and A were utilized as the electrodes for the fruit battery, which one is the positive electrode?

ii. If metal D and C were utilized as the electrodes for the battery, which one is the positive electrode?

Question I-2: Determine how different variables affect the fruit battery

Procedures:

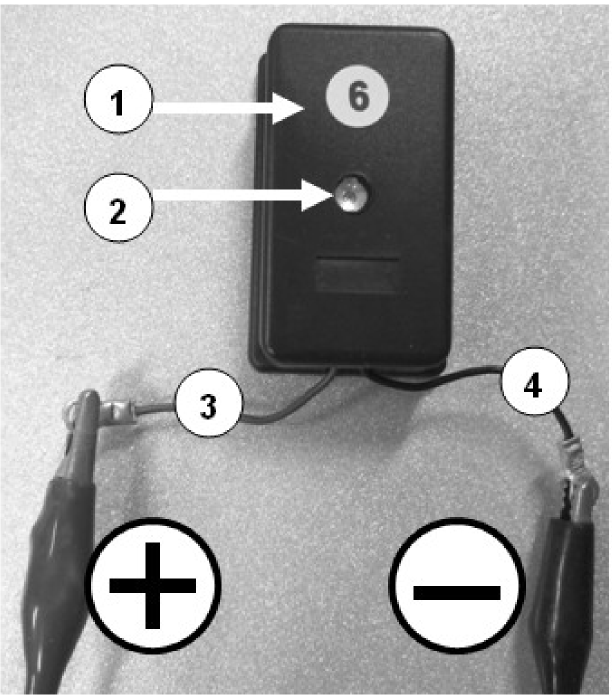
1. Use metal B as the positive electrode (+) and metal C as the negative electrode (-) to assemble the fruit battery.
2. Read Question I-2-a and I-2-b before proceeding with the experiment.
3. Design your own experiment to answer the question I-2-a and I-2-b.

Use "↑" to represent increase, "↓" to represent decrease, and "−" for no change (less than 20%) in answering Questions I-2-a and I-2-b.

I-2-a. Decrease the contact area (at least 3 times) between the metals and the fruit and observe the voltage (V) and current (μA) generated by this battery.

I-2-b. Increase the thickness of the lime slice (at least 3 times) and observe the voltage (V) and current (μA) generated by this battery.

Question I-3. Based on the characteristics of fruit battery, design the simplest device to light up the LED device and answer the following questions:



1. LED device number
   (example: #6)
2. LED
3. Red color wire
4. Black color wire

Hints: A light-emitting diode (LED) is a semiconductor device that emits narrow-spectrum light when it is driven electrically biased in the forward direction of the p-n junction. This effect is called electroluminescence. Current flows easily from the p-side (+) to the n-side (-) of LED, ***but not in the reverse direction. The electroluminescence will not occur otherwise.***

****Write down your LED device number on your answer sheet****

Set up your own experiments to solve the following problems

I-3-a. If a single positive and negative electrodes is used to create the battery unit, how many units are required (the minimum number) to light up the LED device?

I-3-b. Identify the metals chosen for the positive and negative electrodes.

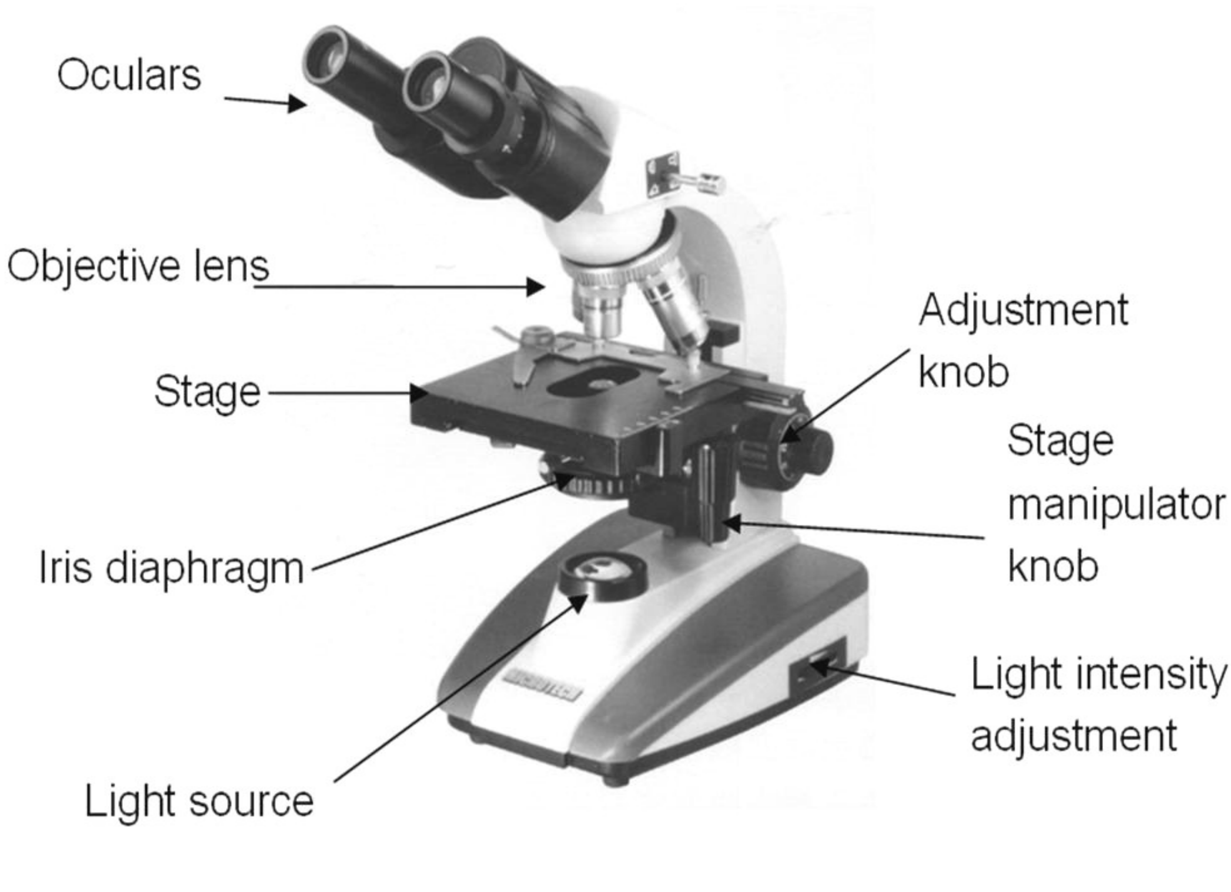
I-3-c. What is the color of the LED luminescence? (Abbreviation: red (R), green (G), blue (B), white (W))

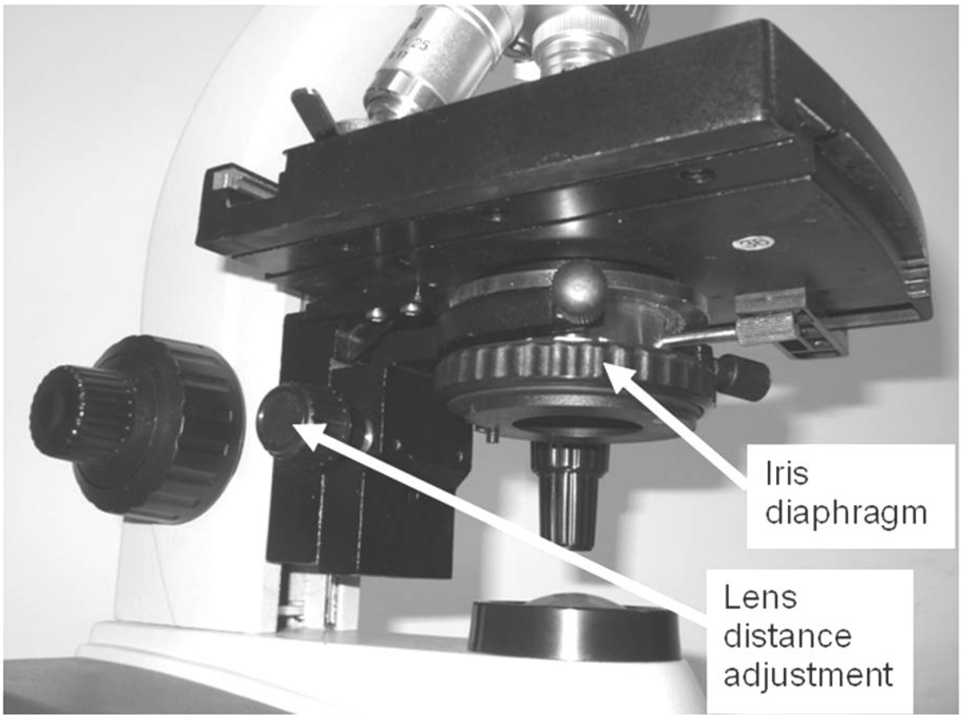
When the LED luminesces, raise your hand to inform the Lab Assistant, who will confirm your answer and sign off on your answer sheet.

Part II: Starch Granules

There are many substances produced during cell metabolism, such as starch granules, lipids, and crystals. Starch, a polysaccharide, is the major storage substances produced by photosynthesis and is the major source of cellular energy. In plant cells, the starch aggregates to form starch granules. The morphology of the starch granule depends on the species of plants. Amylase (an enzyme which could digest starch) is highly abundant in living organisms. After digestion by amylase, the starch will convert to maltose. Questions II-1~ II-2 are designed to assist you to observe the structure of starch granules and to determine the effects of three reagents on it.

You have to use a biological microscope as one shown below. You may ask Lab Assistant for further information.





Using a bright field microscope

- Mount the specimen on the stage
- Turn on the light, optimize the lighting
- Adjust the iris diaphragm.
- Think about what you are looking for
- Focus, locate, and center the specimen
- Adjust eyepiece separation, focus
- Select an objective lens for viewing
- Adjust illumination for the selected objective lens
- To obtain the fine structure of starch granules, you may adjust the iris opening and lens distance from the target.
- Turn off the light.

Question II-1: To observe the structure of starch granules in potato

Procedures:

1. Use the knife to cut the potato and scrape some potato juice (extract) on the slide.
2. Add one drop of 1% iodine solution on the potato juice. Mix them well to stain starch granules as shown in Figure II-1.

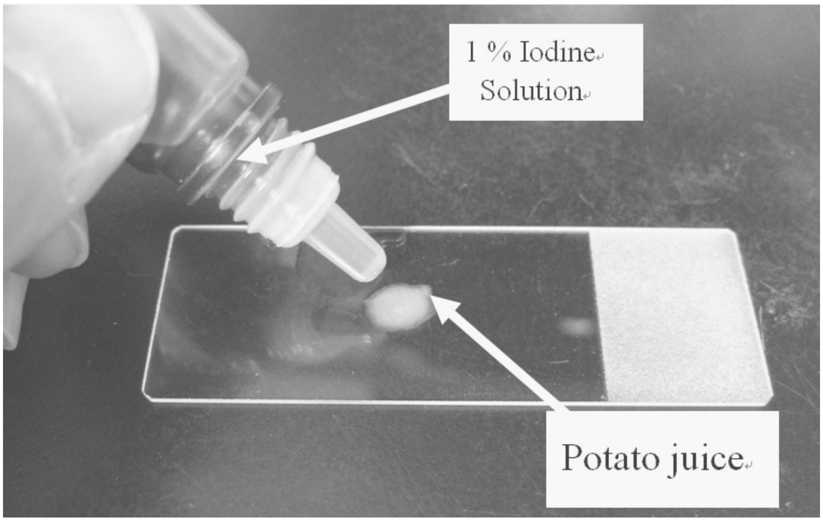


Figure II-1

3. Put the cover slip on your slide as shown in Figure II-2.

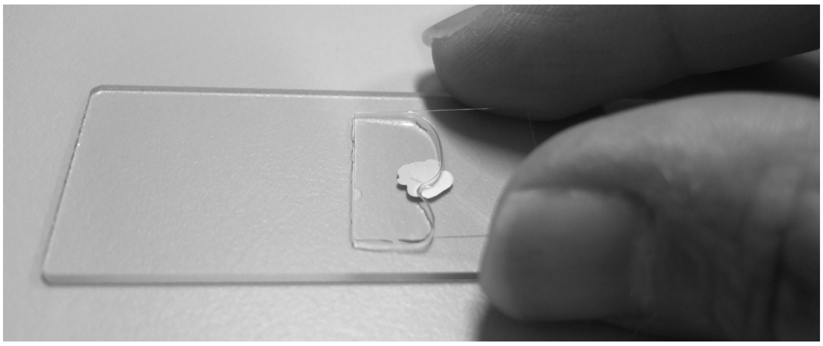


Figure II-2

4. Use paper towel to remove the excess iodine solution along the cover slip.
5. Observe the structure of the starch granules in potato.

II-1 Observe the starch granule in potato by the microscope. Draw the shape and detailed features of one starch granule under 400X (40X objective) magnification of the microscope on your answer sheet.

Question II-2: To determine reactions of reagents on starch granules

Procedures:

1. Use the same procedures of Question II-1 and prepare three more potato starch granules slides.
2. Label the potato slides as sample A, B, and C.
3. Put the slide on the microscope stage and use the adjustment knob to look for the starch granules.
4. Add one drop of reagent A from one side of the cover slip into the sample A as shown in Figure II-3.

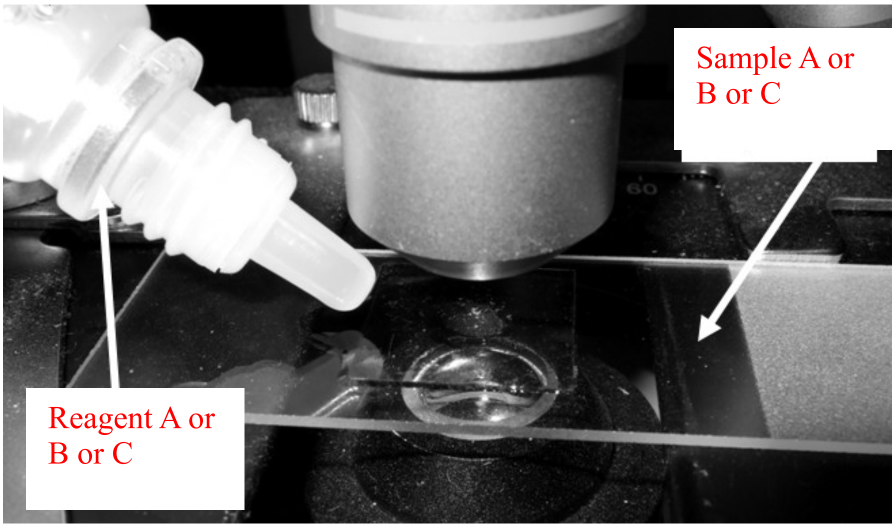


Figure II-3

5. Observe the changes of the potato starch granules on the reagent dropped side by microscope during the first minute.
6. Repeat steps 5 and 6 by using reagents B and C on samples B and C; respectively.
7. Answer Questions II-2-a, II-2-b, and II-2-c.

II-2-a. After adding the reagent A, the potato starch granules were

(A) unchanged (B) swollen only (C) swollen to lyse (D) shrinked

II-2-b. After adding the reagent B, the potato starch granules were

(A) unchanged (B) swollen only (C) swollen to lyse (D) shrinked

II-2-c. After adding the reagent C, the potato granules were

(A) unchanged (B) swollen only (C) swollen to lyse (D) shrinked

Part III: Conductivity of an Electrolyte Solution

Metals are good conductors. Some compounds are also good conductors while dissolved in water, such as sulfuric acid, sodium hydroxide, and nitric acid. We name this type of molecules "electrolytes". Aqueous solution of sucrose or alcohol do not conduct electricity, therefore, they are not electrolytes. It is clear that the physical properties of the molecules determine the conductivity of their aqueous solutions. In this experiment we shall determine the effect of concentration on the conductivities of a given electrolyte. The conductivity of a solution is proportion to the current at constant voltage. In this experiment we measure the current to denote the conductivity.

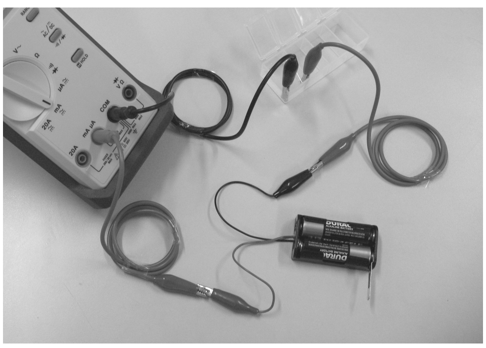
There are three parts in this experiment. In III-1, sodium hydroxide solutions were utilized to test the effect of concentration on the conductivity of these solutions. You need to plot the results and figure out the relationship between conductivity and the concentration of the electrolyte. In III-2, a sodium hydroxide solution of unknown concentration will be given, and you have to measure the conductivity and figure out the concentration by interpolating from the data in the correct figure you plotted in III-1. In III-3, the conventional titration method will be used to determine the concentration of the same unknown sodium hydroxide solution.

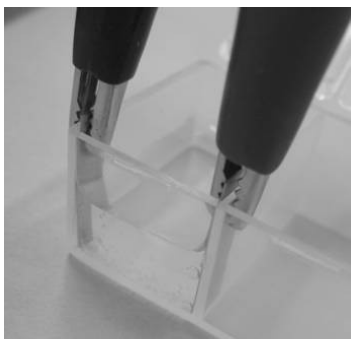
Question III-1: The relationship between sodium hydroxide solution concentration and conductivity

Procedures: ** Record all your data on the answer sheets**

1. Use the 0.5 mol·L^{-1} $NaOH_{(aq)}$ solution provided and the graduated cylinder to prepare 50.0 mL of each of 0.35, 0.25, 0.12, and 0.06 mol·L^{-1} of $NaOH_{(aq)}$ solutions. Transfer the solutions into 100 mL beakers for later use.

2. Fix the Pt electrodes along the inside wall of the plastic box by using alligator clamps and connect them to the 3 V battery box and the Amperemeter as shown below, see also the figures on page 5.





3. Measure out 5.0 mL of 0.06 mol·L^{-1} $NaOH_{(aq)}$ solutions and pour into the plastic box. The solution should not reach the alligator clamps. Make sure all connections are correct then switch the battery box to the "on" position and start counting time. Record the current reading at 30 seconds after switch on.

III-1-a: Record your data in the appropriate place.

4. Repeat step 3 with other $NaOH_{(aq)}$ solutions and record the data.

III-1-b: Plot (a) concentration (in $mol{\cdot}L^{-1}$) v.s. square root of current (in $\sqrt{mA}$),

(b) square root of concentration (in $\sqrt{mol \cdot L^{-1}}$) v.s. current (in mA), and

(c) square root of concentration (in $\sqrt{mol \cdot L^{-1}}$) v.s. current square (in $(mA)^2$) on graph papers in the answer sheets.

III-1-c: Which of the plots in **III-1-b** is the best approximation of a straight line?

Question III-2: Determine the concentration of a $NaOH_{(aq)}$ solution by using conductivity measurements

Procedures:

1. Measure out 5.0 mL of $NaOH_{(aq)}$ solution with unknown concentration, and pour into plastic box.
2. Perform the measuring procedures.

III-2-a: Record the current measured.

III-2-b: Use the graph you decided to be the best straight line in **III-1-b** to determine the concentration of the $NaOH_{(aq)}$ solution by using interpolation.

3. After completed all the current measurements, rinse the Pt electrodes and put them back in their bag. Return it to the Part III basket.

Question III-3: Determine the concentration of a $NaOH_{(aq)}$ solution by using acid-base titration

Procedures:

1. Take 5 mL of 0.25 mol·L^{-1} HCl solution into a test tube. Add a few drops of the indicator and keep it for titration endpoint comparison.
2. Take 5 mL of 0.5 mol·L^{-1} NaOH solution into a test tube. Add a few drops of the indicator and keep it for titration endpoint comparison.
3. Pour HCl solution into the burette.
4. Measure 20.0 mL of the unknown concentration of NaOH solution into a 125 mL Erlenmeyer flask and add a few drops of indicator.
5. Use HCl solution to titrate.

III-3-a: Record the volume used.

6. Repeat steps 4 and 5 as many times as necessary, and calculate the average volume.

III-3-b: Calculate the concentration of the given $NaOH_{(aq)}$ solution.

Part IV: Energy Transfer Associated with Incandescent Lamp

The conductivity (or resistance) of a material will not only vary with the carrier concentration but also vary with temperature. Materials with properties such as volume, color, resistance that vary with temperature may be used as temperature indicator. The temperature scales are different in various professional communities. The most commonly used temperature scales are Celsius and Kelvin as listed in Table IV-1.

Table IV-1: Two commonly used temperature scales.

Name	Symbol	Unit	Relationship
Celsius	T_C	℃	$T_C = T_C$
Kelvin	T	K	$T = T_C + 273$

Kelvin is commonly used in scientific data recording and analysis. For example, Figure IV-1 shows the resistance versus the temperature of a 1 cm tungsten cube (the cross sectional area is 1 cm^2). The vertical axis is the resistance of the tungsten cube with the unit of $\mu\Omega = 10^{-6}\ \Omega$, and the horizontal axis is the temperature in Kelvin.

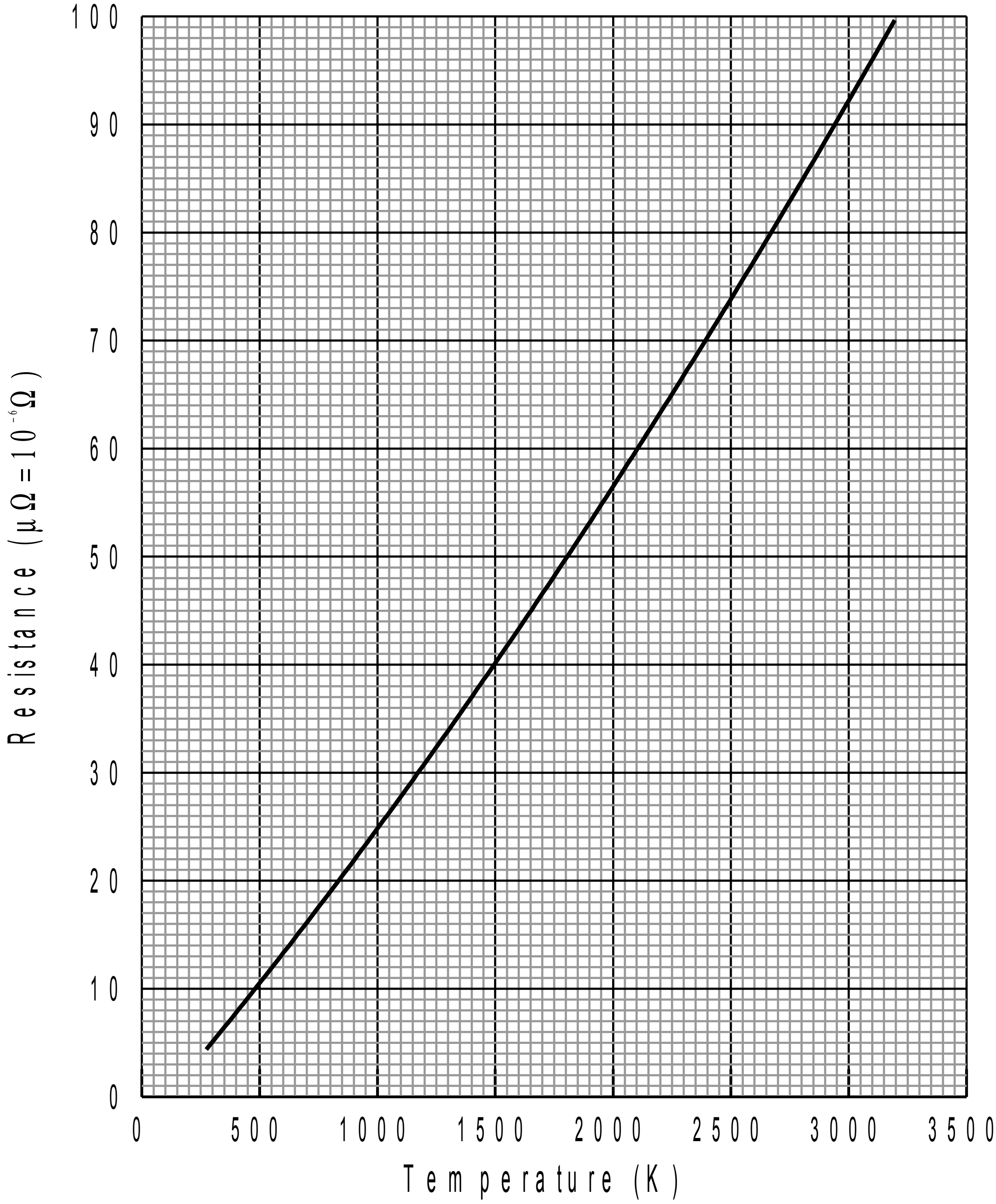


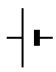
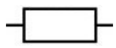
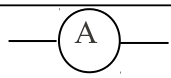
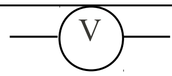
Figure IV-1

IV-1. Read the room temperature from the thermometer. Record your data in Celsius. What is the room temperature in Kelvin?

IV-2. Use the multimeter to measure the room temperature resistance of the tungsten filament in the light bulb.

The circuit symbol used in this part is given in the Table IV-2

Table IV-2: Circuit symbols.

Device	Light bulb	Battery	Resistor	Ampere meter	Volt meter
Symbol					

Connect the battery box (6 V), the light bulb, and the largest resistor as illustrated in the circuit diagram of Figure IV-2. The current (I) and voltage (V) of the filament in the bulb may be measured by multimeters with correct dial setting and wiring.

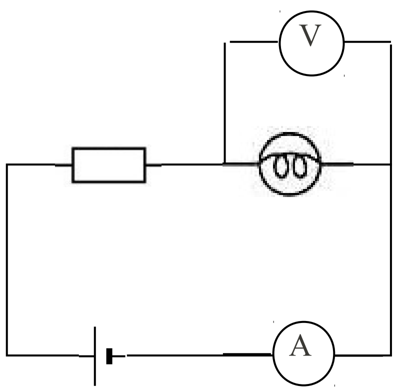


Figure IV-2.

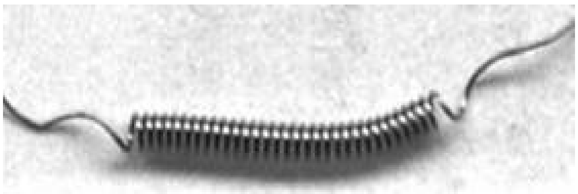
IV-3. You may change the resistor to vary the voltage and current of the light bulb. A data point without a resistor (zero resistance) should be recorded. At least 10 data points are required. Write the data set (*I, V*) in the answer sheet. **Make sure you record and calculate every data to two digits after the decimal point.**

IV-4. From the measured (*I, V*) data, calculate the resistance R and the electric power P of the light bulb corresponding to each pair of voltage V and current I, and fill them into the data table in the answer sheet.

IV-5. Use your data and figure IV-1 to obtain the temperature (*T*) in Kelvin of the tungsten filament in the light bulb corresponding to each pair of voltage V and current I. Record all the calculated results in the data table of the answer sheet.

Hint:

As shown in the magnified picture below, the dimensions of the tungsten filament in the light bulb are quite different from those of the tungsten cube described in the Introduction.



IV-6. Calculate the logarithm of value of the power $\log(P)$ and the logarithm of temperature $\log(T)$, and fill them into the data table in the answer sheet.

IV-7. Plot the logarithm of the electric power, $\log(P)$, versus the logarithm of the temperature, $\log(T)$.

The tungsten filament can transfer its energy to the environment through three channels. They are conduction, convection, and radiation. The powers of energy transfer are the conduction power, P_{CD} , convection power, P_{CV} , and radiation power, P_{RD} , respectively.

Two of the energy transfer channels, the conduction and convection, are mediated through matters, and their total power is proportional to the temperature difference, $\Delta T = (T - T_e)$, between the filament temperature (T) and environment temperature (T_e). While the energy transfer via radiation can propagate through vacuum without any medium. The energy radiation rate is proportional to the power law T^{β} of the filament temperature (T), and β is larger than 1. Therefore, the total power transfer from the hot filament to the environment may be modeled as $P_{tot} = \alpha T^{\beta} + \gamma \Delta T$. Where α and γ are positive constants.

IV-8. Analyze your data, and determine the value of β. Draw necessary curves in the plot, and write down the answers and formulae used in the corresponding blanks.