1 Experimental Exam

Experimental work has many stages. It includes exploring the behaviour of physical phenomena so that an experiment can be designed precisely. We shall therefore introduce the problem and guide you through exploratory tests of the phenomenon.

1.1. Introduction

There are two options for addressing pollution caused by fossil hydrocarbons in electricity generation: so-called alternative (or clean) energy and nuclear energy. Nuclear energy raises safety concerns among the public (perhaps unfounded), while alternative energy is too costly for widespread use. Solar energy is a very popular alternative. However, its characteristics and problems are not well known. We wish to explore some aspects of using this form of energy to generate electricity.

The literature provides information such as the following:

The most common solar cells use the photovoltaic effect: sunlight incident on a two-layer semiconductor device creates a potential difference between the layers. This voltage can drive a current through an external circuit and do useful work. The energy delivered by a photovoltaic device is determined by:

- The type and area of the photosensitive material.
- The intensity of the incident light.
- The wavelength of the incident light.

Polycrystalline silicon solar cells have efficiencies below 20%, and amorphous silicon cells around 10%, both because of internal energy losses.

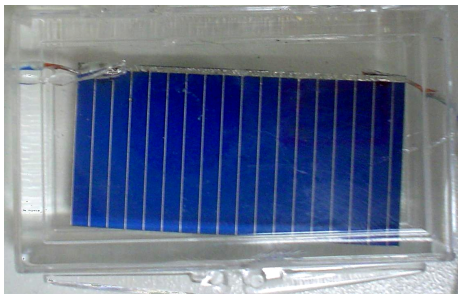
An important feature of photovoltaic cells is that their voltage does not depend on cell size and remains fairly constant as the light intensity changes.

The electric current in these devices is almost directly proportional to the light intensity and the cell size. To compare different cells, they are classified by current density, measured in amperes per square centimetre.

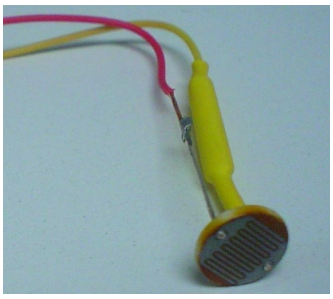
1.2. Materials

The following are supplied (use those you consider necessary):

1. One 12 V, 4 W white-light bulb simulating the Sun (a spare bulb is supplied).
2. One 12 V battery and one 9 V battery.
3. One miniature solar cell.
4. Two multimeters.
5. One 1 kΩ potentiometer (rheostat).
6. One electrical *breadboard*.
7. Wires.
8. One photoresistor.
9. One ruler.



Solar cell



Photoresistor

1.3. Part 1 of the problem: solar cell study

The aim is to study the relationship between the voltage and current supplied by a solar cell.

First familiarise yourself with the equipment.

1. Briefly describe the procedure you will use to establish the voltage–current relationship of the solar cell. (1 point).
2. Draw a circuit diagram (represent the solar cell as a battery). (1 point).
3. Tabulate the measured values. (1 point).
4. Plot the corresponding graph. (2 points).
5. Compare this graph with the one that would be obtained by replacing the cell with a battery having the same open-circuit voltage. (1 point).
6. Determine the maximum power supplied by the solar cell. (2 points).
7. If increasing light intensity increases the current but not the voltage, how would you connect several cells to obtain a higher voltage? (2 points).
8. Current increases with light intensity and solar-cell size (illuminated area). If you cannot increase the light intensity, how would you increase the circuit current while keeping the voltage constant? (2 points).

1.4. Part 2 of the problem: light intensity and photoresistor resistance

We wish to find the relationship between a photodetector's response and the light intensity it receives. We shall explore this using a simple photoresistor, a small device whose resistance depends on illuminance E according to $R = A/E^{\alpha}$, where A is a constant and α is an exponent between 0,50 and 1,0.

For a ***point*** light source, light intensity varies with distance d from the source as $1/d^2$. We shall regard this as an acceptable approximation here.

1. Draw the circuit used to determine the relationship between light intensity and photoresistor resistance as a function of distance from the light source. (2 points).
2. Determine α for your particular device. (4 points).
3. Estimate the uncertainty in α. (2 points).