Identifying the wavelength that generates the most voltage and current in a solar panel

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SUMMARY

Solar power is a potential solution for addressing climate change. There is limited research on how different wavelengths of light affect solar cells, and researchers have come to conflicting conclusions. Determining the most efficient wavelength of light would allow us to improve solar panel efficiency and make panels more cost-effective and desirable for adoption by the general public. A color filter is relatively inexpensive, and it can enhance the efficiency of a solar panel. Ultimately, it can help save the environment by (1) making solar panels as efficient as possible, (2) making society less dependent on fossil fuels, and (3) speeding up adoption of solar power. Therefore, this study focused on determining which wavelength of light generates the most voltage and current from a solar panel as measured by a Raspberry Pi coded to function as a multimeter. We measured the voltage and current that the solar panel generated in the absence or presence of different filters, which produce different wavelengths of light. Learning which, if any, color filter generates the most voltage and current can improve and promote solar power use. We determined that the yellow filter produced the greatest voltage and current compared to using a solar panel without a filter or a red, orange, green, blue, and purple color filter. Our results suggest that yellow color filters can enhance the voltage and current capabilities of solar panels. The findings offer a relatively low-cost solution to increasing the efficiency of solar panels.

INTRODUCTION

The topic of solar panels in general is discussed in the world by power companies and people wanting to switch to cleaner energy for environmental and economic reasons. Today, parts of society use solar panels in their daily life. We might be able to use this technology even more in the future when people's demand for cleaner energy sources increases. Using solar energy is an optimal solution to address climate change (1). Solar panels are made up of connected solar cells that are arranged to produce electricity when placed under sunlight (2). Solar energy offers an ideal alternative way to generate electricity because it avoids the negative environmental impact caused by burning fossil fuels (2).

Ensuring solar energy is converted into electricity as efficiently as possible is a priority (3). The primary barrier to adoption of solar energy is the limited efficiency of solar cells (3). There are conflicting reports on whether applying a color filter to the surface of a solar panel generates more voltage and current from a solar panel (1-8). Some studies have found that no filter was the most efficient for energy production (1-6). On the other hand, a few studies found a color filter was the most efficient (7,8). A color between yellow and red has been proposed to be the most efficient for energy production (7). However, violet has also been proposed (8). For studies that found that no filter was the most efficient for energy production, a variety of color filters, including red, purple, magenta, and yellow, have been found to be the most efficient after no filter (1-6).

Learning which, if any, color filter generates the most voltage and current can help facilitate the adoption of solar power. This study aimed to determine which wavelength of light generates the most voltage and current from a solar panel as measured by a Raspberry Pi coded to function as a multimeter. The multimeter data was recorded onto the Raspberry Pi, which is a self-built computer that displays the data. We hypothesized that if the light wavelength is 622 to 780 nanometers, corresponding to the color red, then the solar panel will generate the most voltage and current as measured by the multimeter because red has the longest wavelength and carries less energy than other wavelengths. Therefore, red light would not heat the solar panel up as much and would allow the panel to operate at a cooler temperature and be more efficient.

RESULTS

The purpose of this study was to determine which wavelength of light generates the most voltage and current from a solar panel. To test the effect of different colored filters, we placed a solar panel with and without color filters under a white light lamp and measured voltage and current output with a multimeter. The measurements were taken after exposure to light for 30 seconds. The voltage and current measurements were then averaged over ten trials for each condition. As a control, the solar panel was covered with black construction paper for 30 seconds before each trial. The voltage and current readings when the black construction paper completely covers the solar panel was zero (data not shown).

The controlled variables were light intensity, distance between light source and solar panel, length of time the light shines on the solar panel, thickness of the filter, and solar panel tilt. The measured variables were the voltage and current the solar panel generated. The independent or manipulated variable was the wavelength of light.

For voltage measurements, the ranking of filters from highest voltage to lowest was yellow, no filter, red, orange, green, purple, and blue (**Figure 1**). The average voltages ranged from 2.55 ± 0.06 V to 3.51 ± 0.04 V, suggesting that
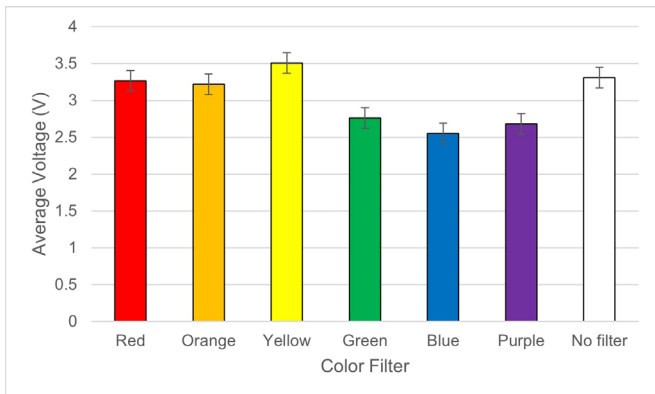
Figure 1. Average voltage for each color filter. Average voltage (V) of solar panel covered with the indicated color filter over ten trials. The error bars indicate standard error.

Figure 2. Average current for each color filter. Average current (µA) of solar panel covered with the indicated color filter over ten trials. The error bars indicate standard error.

the solar panel retained some degree of energy production with or without filters (**Figure 1**). The average voltage when a yellow filter was applied was 3.51 ± 0.04 V, which is % greater than the average voltage when no filter was applied, 3.31 ± 0.06 V (**Table 1**).

For current measurements, the ranking of filters from highest current to lowest was yellow, no filter, blue, orange, purple, red, and green (**Figure 2**). The average currents ranged from 369.6 ± 3.8 µA to 811 ± 7.2 µA, suggesting that the solar panel maintained some level of electricity flow with or without filters (**Figure 2**). The average current when a yellow filter was applied was 811 ± 7.2 µA, which is 5% greater than the average current when no filter was applied, 772.5 ± 3.2 µA (**Table 2**).

DISCUSSION

This study aimed to identify the wavelength of light that generates the most voltage and current from a solar panel. We hypothesized that if the light wavelength is the color red, then the solar panel will generate the greatest voltage and current. Measuring the voltage of a solar panel with or without color filters provided insight on whether having a color filter affected solar panel performance. The yellow filter generated
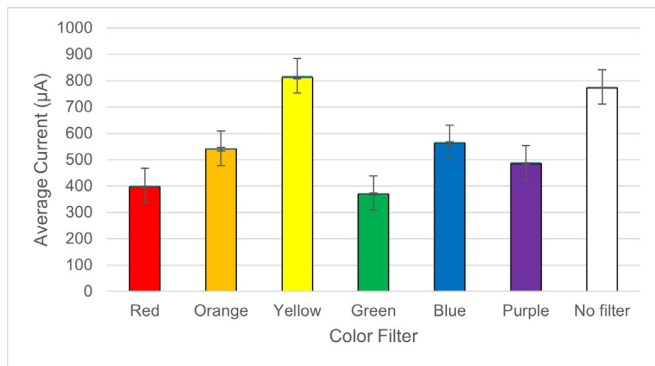
the highest voltage and current, followed by no filter, for both measurements. The remaining colors ranked differently for the two measurements (**Figures 1,2**).

The data did not support our hypothesis that applying a red filter to the solar panel would generate the most voltage and current as measured by the multimeter. Instead, the results indicated that a yellow filter produced the most voltage and current. The wavelength of yellow is 577 to 597 nanometers, which is less than the red wavelength. A yellow filter allows yellow light through but blocks other wavelengths to pass through. Having no filter allows all light wavelengths to pass through, and it might be expected to generate the most electricity since it is not blocking any wavelengths. The yellow filter blocking the other wavelengths may have improved solar cell performance because the filter itself decreased heat transfer to the solar cell, allowing the solar cell to be more energy efficient. One study found that after no filter, a magenta color filter was the most effective, likely because the filter also reduced the temperature of the solar panel (4). Another study found that a violet color filter resulted in the lowest solar panel temperature and had the best electrical performance in the study (8). Therefore, it is possible that overheating produces less solar electricity.

Color Filter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Average
Red	3.25	3.28	3.23	3.30	3.27	3.29	3.32	3.26	3.24	3.23	3.27 ± 0.03
Orange	3.21	3.15	3.20	3.17	3.40	3.24	3.17	3.19	3.20	3.27	3.22 ± 0.07
Yellow	3.51	3.47	3.45	3.50	3.53	3.54	3.44	3.57	3.52	3.53	3.51 ± 0.04
Green	2.75	2.81	2.80	2.74	2.72	2.70	2.83	2.82	2.74	2.71	2.76 ± 0.05
Blue	2.56	2.47	2.61	2.53	2.64	2.47	2.60	2.49	2.60	2.55	2.55 ± 0.06
Purple	2.68	2.76	2.63	2.72	2.58	2.70	2.65	2.71	2.72	2.66	2.68 ± 0.05
No filter	3.30	3.36	3.24	3.34	3.40	3.29	3.35	3.23	3.30	3.27	3.31 ± 0.06

Table 1. Average voltage for each color filter. Average voltage (V) of solar panel covered with the indicated color filter over ten trials.

Color Filter	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Average
Red	398	390	401	400	389	394	396	405	399	397	396.9 ± 4.9
Orange	541	540	538	545	543	537	539	542	536	540	540.1 ± 2.8
Yellow	809	802	798	816	817	818	812	820	807	811	811.0 ± 7.2
Green	373	368	364	375	370	368	374	364	371	369	369.6 ± 3.8
Blue	563	565	560	567	561	558	563	562	569	558	562.6 ± 3.6
Purple	487	484	480	490	481	482	491	492	484	483	485.4 ± 4.3
No filter	770	774	776	775	771	768	774	775	767	775	772.5 ± 3.2

Table 2. Average current for each color filter. Average current (µA) of solar panel covered with the indicated color filter over ten trials.

Throughout this experiment, there were a few challenges and issues. The specialized color filters did not cover the entire solar panel. Placing black construction paper over the panel areas not covered by the color filter created a seamless system with no gaps, which was used in all trials for recording data, to maintain consistency. Since each trial had a consistent area available for a colored filter or no filter, the results could be generalized.

Future research should be done to investigate different shades of yellow filters to see which one is the most effective. It would also be interesting to explore additional variables, including light intensity, distance between the light source and solar panel, temperature of the solar panel, tilt of the solar panel, and the type of solar panel used. Further experiments could reveal more data regarding which wavelengths optimize energy production.

In conclusion, the data collected and analyzed showing yellow was the optimal color, suggesting that using a yellow filter for a solar panel may be a cost-effective way to increase its efficiency.

MATERIALS AND METHODS

Python 3 code was written (**Appendix**) to allow the Raspberry Pi, a single-board computer, to function as a multimeter. On an afternoon, under a LBW Grow Light (a plant growing lamp), the Sunnytech 4.57" x 4.57" 1.25w 5v 250ma minismall solar panel module DIY polysilicon solar epoxy cell charger B019 was attached to the CanaKit Raspberry Pi 3 terminal using alligator clips. The Raspberry Pi was connected to a laptop and the FREENOVE Ultimate Starter Kit for Raspberry Pi's LCD screen was attached. A Selens 3.74" x 2.56" transparent color correction lighting film plastic sheet was laid against the upper left corner of a black construction paper. An outline of the filter was drawn and cut. The solar panel was covered with black construction paper for 30 seconds to zero the instrument. The solar panel was covered with black cut construction paper such that the upper left corner was exposed. After 30 seconds, the voltage and current output generated with no filter was taken from the LCD screen. This procedure was repeated nine times for a total of ten trials. Then, the procedure was completed with a Selens red color correction lighting film plastic sheet in the upper left corner for ten trials. This was repeated with Selens orange, yellow, green, blue, and purple sheets.

ACKNOWLEDGMENTS

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1 **Appendix**

2 The following is the Python code that allows Raspberry Pi to function as a multimeter.

3

```
4   from PCF8574 import PCF8574_GPIO
5   from Adafruit_LCD1602 import Adafruit_CharLCD

7   from time import sleep, strftime
8   from datetime import datetime

10  import smbus

12  class ADCDevice(object):
13      def __init__(self):
14          self.cmd = 0
15          self.address = 0
16          self.bus=smbus.SMBus(1)
17          # print("ADCDevice init")

19      def detectI2C(self,addr):
20          try:
21              self.bus.write_byte(addr,0)
22              print("Found device in address 0x%x"%(addr))
23              return True
24          except:
25              print("Not found device in address 0x%x"%(addr))
26              return False

28      def close(self):
29          self.bus.close()

31  class PCF8591(ADCDevice):
32      def __init__(self):
33          super(PCF8591, self).__init__()
34          self.cmd = 0x40     # The default command for PCF8591 is 0x40.
35          self.address = 0x48 # 0x48 is the default i2c address for PCF8591 Module.

37      def analogRead(self, chn): # PCF8591 has 4 ADC input pins, chn:0,1,2,3
38          value = self.bus.read_byte_data(self.address, self.cmd+chn)
39          value = self.bus.read_byte_data(self.address, self.cmd+chn)
40          return value

42      def analogWrite(self,value): # write DAC value
43          self.bus.write_byte_data(address,cmd,value)

45  class ADS7830(ADCDevice):
```

```python
46        def __init__(self):
47            super(ADS7830, self).__init__()
48            self.cmd = 0x84
49            self.address = 0x4b # 0x4b is the default i2c address for ADS7830 Module.
50
51        def analogRead(self, chn): # ADS7830 has 8 ADC input pins, chn:0,1,2,3,4,5,6,7
52            value = self.bus.read_byte_data(self.address, self.cmd|(((chn<<2 |
53    chn>>1)&0x07)<<4))
54            return value
55
56    def get_ADC():
57        adc_device = ADCDevice()
58
59        if(adc_device.detectI2C(0x48)):                 # Detect the pcf8591
60            adc = PCF8591()
61        elif(adc_device.detectI2C(0x4b)):               # Detect the ads7830
62            adc = ADS7830()
63        else:
64            print("No correct I2C address found, \n"
65            "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
66            "Program Exit. \n");
67            exit(-1)
68        return adc
69
70    def ClearScreen(x = 0, y = 0):
71        lcd.clear()
72        lcd.setCursor(x,y)
73
74    def LCDPrint(message, clear = False, newLine = True):
75        if clear:
76            ClearScreen()
77        if newLine:
78            lcd.message(message+'\n')
79        else:
80            lcd.message(message)
81
82    def loop():
83        mcp.output(3,1)  #turn on LCD backlight
84        lcd.begin(16,2)  #set 16 LCD columns, 2 lines
85        while(True):
86            LCDPrint("hello", clear = True, newLine = True)
87            LCDPrint("Amari")
88            sleep(4)
89
90    def destroy():
91        lcd.clear()
```

```
92
93     PCF8574_address = 0x27 # I2C address of PCF8574 chip
94     PCF8574A_address = 0x3F # I2C address of PCF8574A chip
95
96     try:
97         mcp = PCF8574_GPIO(PCF8574_address)
98     except:
99         try:
100            mcp = PCF8574_GPIO(PCF8574A_address)
101        except:
102            print('I2C Address Error')
103            exit(1)
104
105    lcd = Adafruit_CharLCD(pin_rs = 0, pin_e = 2, pins_db = [4, 5, 6, 7], GPIO = mcp)
106
107    if __name__ == '__main__':
108        print('Program is starting...')
109        try:
110            loop()
111        except KeyboardInterrupt:
112            destroy()
113
```