Measurement of Solar Constant using Simple Route

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Abstract:

The radiation emitted by the sun and reaching the earth comprises long electromagnetic waves. The solar constant has been measured using glass beaker equipment for six days in the month of February 2020. According to our results, the solar constant value indicates that the value is not fixed but varies with time and these variations happened due to the solar activities such as weather, climates, etc. In the present article, we discussed the locally fabricated low-cost device of glass beaker which is used to evaluate the solar constant and the calculated average black ink added water value is 1387.19 W/m^2 at the ground surface.

Keywords: Beakers, Thermometer, Stand, Solar Constant, Solar Radiation

1. Introduction:

As we know, the sun is a source of energy that drives the life cycle on earth. The sun radiates its energy for the earth’s climate system on the top of the earth's atmosphere viz. UV radiation, visible light, and infrared radiation. In the solar system, the sun is the largest planet whose radius is approximately 6.9 x 105 km made with very hot gas have generated by the fusion reaction. There is a huge number of sun rays were bombarded on to the earth directly and the human being is utilized it in the form of energy as per their priceless usefulness. However, solar energy is a renewable, non-conservative, non-pollutant medium and everyone can use with free of cost. Hence, up to date, a more number of researches are already going on this hot topic. According to the literature survey, 430 quintillion joules per hr from the sun hit on the earth and the total amount of energy per year used by humans is 410 quintillion joules only, which is a massive difference. Hence, due to the hitting of sun rays, the large distance of solar radiation received on earth is almost parallel and it appears to be equivalent to that coming from the black surface at 5767 ^oK [1]. It would need to measure the solar constant of the hitting solar radiation on the earth's surface. The solar constant is the rate at which solar radiation received on the earth's surface normal to the sun’s path in free space at the earth's mean distance from the sun [2]. Because of the distance of the sun, activity varies throughout the year, and due to this reason, the rate of arrival of solar radiation alters regularly. The earth is closest to the sun in the summer and away in the winter which causes the solar constant to vary gradually.

The solar constant included all types of solar radiations and it is measured by the satellite in between 1.36 kW/ m^2 to 1.362 kW/ m^2, respectively [3]. The first measurement of solar constant was done by C. Pouillet in 1818 and this concept was simplified by JL Dufresne and colleague using pyrheliometer and achieved the value of 1228 W/ m^2 [4]. Moreover, this evolution gets a new platform to measure a variety of solar constat with their altitude and hence, various researchers attempted the new values of solar constant like J. Violle of 1.7 kW/m^2, S. Pierpont Langely of 2.903 kW/m^2, C. G. Abbot of 1.465 kW/m^2[5]. These solar constants measurements have been taken by the various researches are more complicated as well as expensive. However, the achievable range is also normal. But, here we demonstrated the new conceptual route to measure the solar constant in an easy way with cheap in cost. Thus, by our experiment, we obtained the solar constant value is ~1.387 kW/m^2.

The objective of this work is to measure and compare the solar constant values which are obtained by various researchers. This study beneficial for the new comers who may interested in the areas of energy studies. The new easy way of measurement of solar constants, its methods and results have thoroughly discussed in this article.

2. Materials and methods:

There are various low cost methods are exists to measure the solar constants. Here, we used the simplest route such as glass beaker and water which added the ink heated with glass a thermometer with help of tight lid [6]. In this method, the components used like 1 liter of borosil glass beaker, a thermometer, adjustable stand and different color of writing ink respectively. This experiment was carried out in the last week of February 2020. The beaker was filled with 300 ml (i.e. 0.3 kg) water with increasing amount of black, blue and red ink drops to change the transparency of the host compound. The thermometer is inserted such a way that the air should not be entering inside the beaker. After that, the stable system has move into the sunlight contact where the solar radiation incident normally on its surface and measured the readings. Here, some of the notable value such as surface area is 190.35 x 10^{-4} m^2, specific heat of water (S) is 4186 J/kg-˚C, respectively.

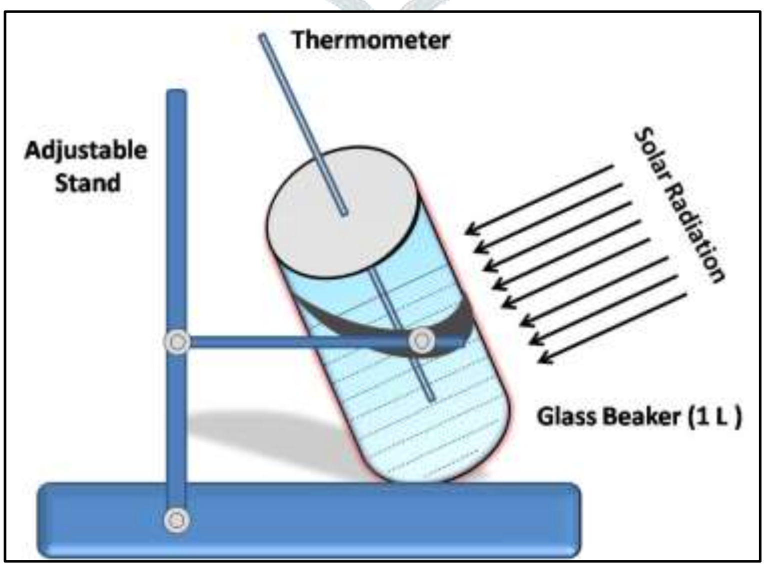

Figure 1: Experimental Set-up of Solar Constant Measurement.

3. Result Discussion:

The following measurement was carried out during the experiment in the order to calculate a solar constant. Here, we mentioned that the results taken for six consecutive days from 11.30 am onwards.

Table 1: The given table was recorded at 01. 00 pm for throughout the readings.

Days	Water Type	Initial Temp. (˚C)	Final Temp.	$\left(\frac{\Delta T}{t}\right)_{mean}$ (x10^{-3})	E_{ave} (J/s.m^2)	Solar constant (G_{SC})	G_{SC} Average
1	Normal	27	37	6.544	431.70	1208.76	-
2	Added 2 ml Black ink	33	39	8.587	566.53	1586.28	1387.19
3	Added 4 ml Black ink	29	39	6.317	416.79	1167.01	
4	Added 6 ml black ink	39	49	7.623	502.96	1408.28	
5	Added 4 ml blue ink	35	45	6.709	442.66	1239.44	-
6	Added 4 ml Red ink	31	41	5.623	371.02	1038.86	-

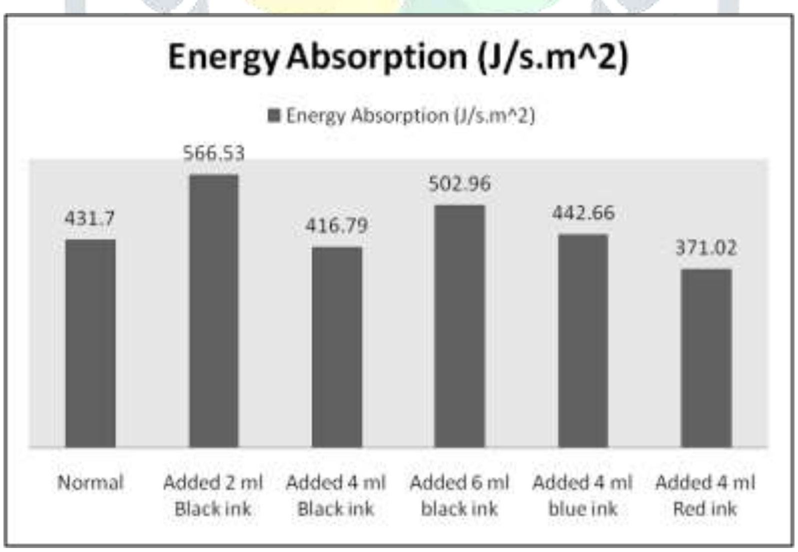

Figure 2: Histogram of different types of liquid Vs Energy absorption.

The period of exposure and their corresponding temperature are given in the table 1. The maximum energy absorbed by 2 ml of black ink added water shows 566.53 $\frac{joule}{s-m^2}$ and minimum observed for red ink added water shows 371.02 $\frac{joule}{s-m^2}$, as shown in Fig. 2. The detailed calculation of the obtained value were made by the below expression,

Solar energy absorbed (or received) by water per second is

$$Q = SM\left(\frac{\Delta T}{t}\right)_{average} \frac{Joules}{sec}. \quad (1)$$

Here, S is the specific heat of water (cal-gm^{-1}C^{-1}), M is the Mass of water taken in 'gm' and 'Q' is the specific heat capacity.

Average energy collected per unit of surface area

$$E_{av} = \frac{Q}{A} \quad \frac{joule}{s-m^2} \quad (2)$$

Here, A is the exposure area respectively.

$$\text{Solar constant } (G_{SC}) = 2\ X\ E_{av}\ X\ Fc\ \frac{W}{m^2}.$$

Therefore, according to the expression, the calculated data was incorporated in table 1. It was observed that the temperature varies due to the weather on a particular day. This means Red-colored absorbed less amount of solar radiation compared to others. As we know, light colors such as yellow, red, and blue are reflected the heat [7]. Here, for black ink added water observed a massive variation in energy absorption. The minor quantity (2 ml) of black ink shows a better response than normal water and other colors added water. Hence, we strongly mentioned that the standard solar constant values (1366.10 W/m2) are quite similar to the calculated average values (1387 W/m2) for black ink added water. Moreover, the Akpootu and Gana have found the average solar constant values of 1381.23 W/m2 by the locally fabricated low-cost facility of the aluminum cylinder [8]. According to our experiments, we conclude that the solar constant value is always flexible and not constant due to the weather situation, shown in Fig. 3.

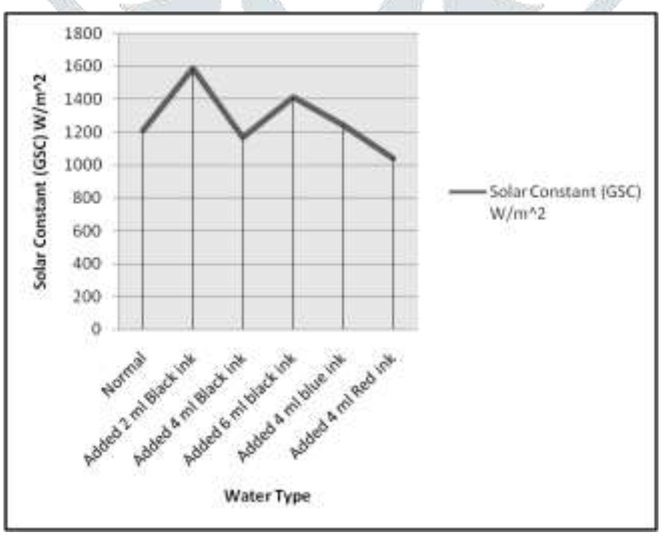

Figure 3: The spectra indicate type of water Vs Solar Constant.

4. Conclusion:

The present work was carried out in the location of Karjat, Dist-Ahmednagar, MH, India (Latitude: 18.571192 and Longitude: 75.0241) for six days in the month of February 2020. We choose the period of the end of the winter season during the clear weather. We studied for six samples and obtained a remarkable result for the sample of black in added water. Here, we noticed for the solar constant values of normal water show 1208.76 and other samples also show the variation as per their properties. But, we strongly mentioned that the average value of black ink added liquid shows superior results (i.e. 1387.19 W/m^2) which are quite similar to the standard solar constant values available in the literature and elsewhere.

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