Inverse-square law

Task and equipment

Information for teachers

Additional Information

For the setup and performance of the experiment it is important that the room is darkened and that the solar cell is orientated in such a way that it can pick up only a small amount of stray light. (This means that in the classroom the solar cells should point towards the walls so that the students do not interfere with one another.)
The solar cell is in part covered with cardboard so that the reference area for the (almost) perpendicular incident light is equal. If the entire solar cell is used the angles of incidence are very different if the solar cell is close to the light source.

Background

Light spreads from the light source in an almost spherical shape (spherical wave). At the same time the light intensity is distributed uniformly across the surface of the sphere. The formula for the calculating of the surface area of a sphere is: O = 4xπxr2, this means the area increases in proportion to the square of the radius and therefor the intensity falls in proportion to the square of the distance from the light source.

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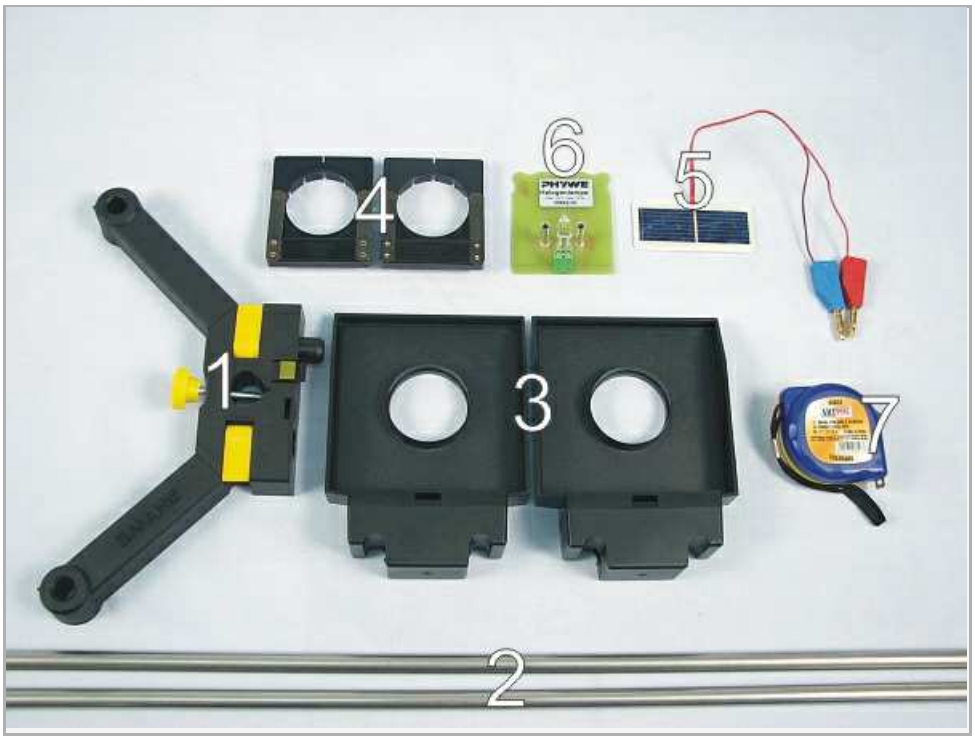
Task and equipment

Task

How does the brightness of light change with increasing distance?

When one moves away from a light source it becomes darker. Everybody knows this. In this experiment you will derive a relationship between the distance from a light source and the light intensity.

Equipment



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Position No.	Material	Order No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
3	Slide mount without angle scale	09851-02	2
4	Diaphragm holder, attachable	11604-09	2
5	Halogen lamp, 12 V/10 W, mounted with 4 mm plugs	09852-00	1
6	Solar cell 2.5 x5 cm, with plugs	06752-11	1
7	Measuring tape, l = 2 m	09936-00	1
Additional material			
8	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
9	DMM with NiCr-Ni thermo couple	07122-00	1
	Connecting cord, 32 A, 750 mm, red	07362-01	1
	Connecting cord, 32 A, 750 mm, blue	07362-04	1
	Piece of cardboard		

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Set-up and procedure

Set-up

- Place the halogen lamp with one of the mounts onto the support and connect it to the power supply.

Fig. 1

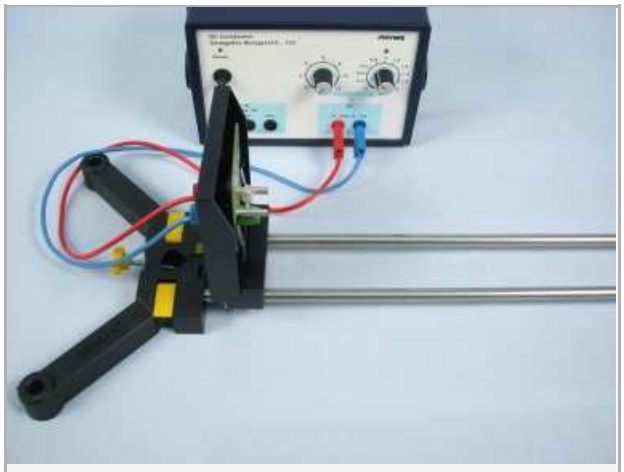

Fig. 2

- Cut out a piece of cardboard and cover the solar cell with it, leaving free an area of approx. 25x25 mm (figure 3-6).

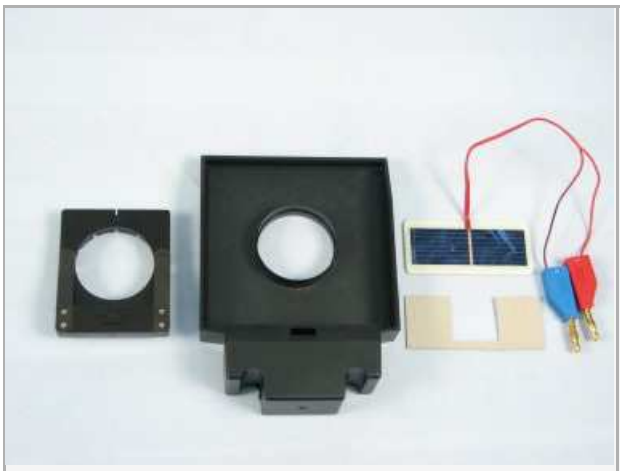

Fig. 3

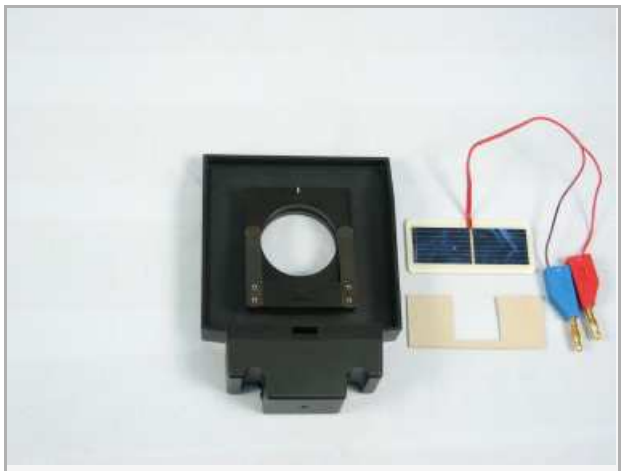

Fig. 4

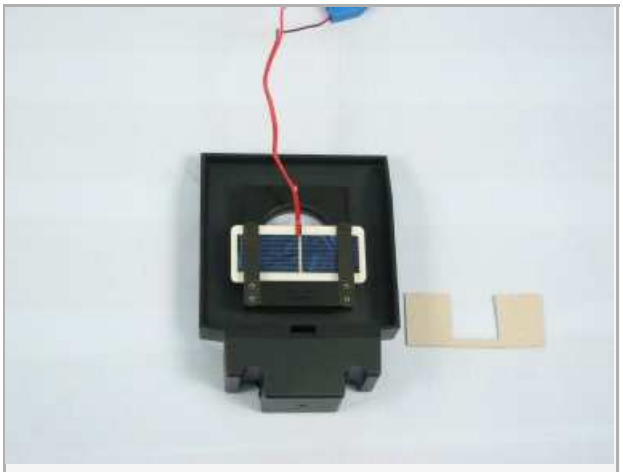

Fig. 5

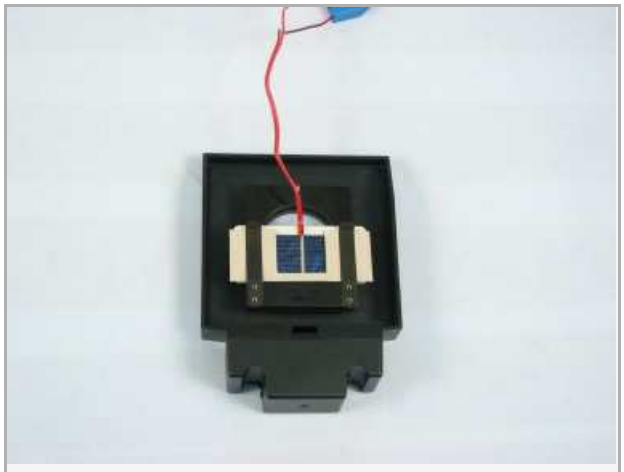

Fig. 6

- Place the solar cell in one of the mounts onto the support opposite to the halogen lamp in such a way that the feet of the mounts make contact. While setting up, ensure that the solar cell is located on the horizontal centre axis of the aperture holder.

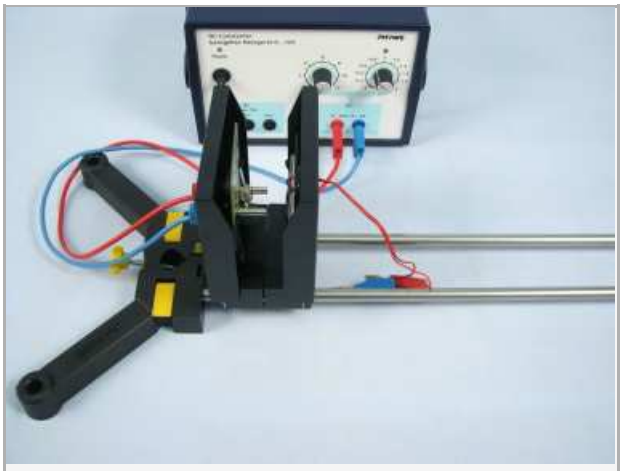

Fig. 7

- A multimeter is connected to the solar cell as an ammeter with the measuring range 2 mA.

Fig. 8

Procedure

• Set the power supply to 12 V.
• Measure the photo-electric current at the solar cell after 10 seconds and record it in table 1. (The 10 seconds are required to allow the halogen lamp to heat up.) The photo-electric current is measured in this experiment in order to determine the intensity of the light - the measured photo-electric current is proportional to the intensity.

Fig. 8

• Increase the distance of the solar cell from the light source as specified in table 1. Here it is the distance between the white lines on the mount feet that is measured. The corresponding photo-electric current is recorded.
• In the end, the supply voltage of the halogen lamp is set to zero and a reference measurement is taken for the solar cell in order to be able to exclude any offset current from the subsequent calculation.

Fig. 9

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Report: Inverse-square law

Result - Table 1

1. Enter the new value in the column 'Distance from light source to solar cell'.
2. In order to determine the distance of the light source from the solar cell the constant value of 1.8 cm is substracted from the value in column 1.
3. In the column 'Photo-electric current - corrected' the value from the column 'Photo-electric current' is entered minus the value for 'Photo-electric current without lamp'.
4. Calculate y*x, $y*x^2$, $y*x^3$ and $y*x^4$ and enter the values in the associated columns.
   x is Distance from light source to solar cell in c
   y is Photo-electric current (corrected)

	Photo-electric current without lamp	0.06 [1]				
Distance between the mounts in cm	Distance from light source to solar cell in c (x)	Photo-electric current in mA	Photo-electric current - corrected in mA (y)	y*x	$y*x^2$	$y*x^4$
5.5	3.7 [1]	42.19 [1]	42.13 [1]	156 [1]	577 [1]	2.134 [1]
6.5	4.7 [1]	25.34 [1]	25.28 [1]	119 [1]	558 [1]	2.625 [1]
7.5	5.7 [1]	16.60 [1]	16.54 [1]	94 [1]	537 [1]	3.063 [1]
8.5	6.7 [1]	11.56 [1]	11.50 [1]	77 [1]	516 [1]	3.459 [1]
9.5	7.7 [1]	8.65 [1]	8.59 [1]	66 [1]	509 [1]	3.922 [1]
10.5	8.7 [1]	6.56 [1]	6.50 [1]	57 [1]	492 [1]	4.280 [1]
11.5	9.7 [1]	5.26 [1]	5.20 [1]	50 [1]	489 [1]	4.746 [1]
12.5	10.7 [1]	4.27 [1]	4.21 [1]	45 [1]	482 [1]	5.157 [1]
13.5	11.7 [1]	3.59 [1]	3.53 [1]	41 [1]	483 [1]	5.654 [1]
14.5	12.7 [1]	3.06 [1]	3.00 [1]	38 [1]	484 [1]	6.145 [1]
15.5	13.7 [1]	2.66 [1]	2.60 [1]	36 [1]	488 [1]	6.686 [1]
20.5	18.7 [1]	1.51 [1]	1.45 [1]	27 [1]	507 [1]	9.482 [1]
25.5	23.7 [1]	0.99 [1]	0.93 [1]	22 [1]	522 [1]	12.380 [1]
30.5	28.7 [1]	0.71 [1]	0.65 [1]	19 [1]	535 [1]	15.366 [1]
35.5	33.7 [1]	0.53 [1]	0.47 [1]	16 [1]	534 [1]	17.988 [1]
40.5	38.7 [1]	0.42 [1]	0.36 [1]	14 [1]	539 [1]	20.866 [1]
45.5	43.7 [1]	0.34 [1]	0.28 [1]	12 [1]	535 [1]	23.367 [1]

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Evaluation - Question 1

Make an hypothesis for the relationship between the distance and the value of the measured intensity (proportional to the photo-electric current).

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Evaluation - Question 2

The diagram suggests that the two values are inversely-proportional. In order to confirm this assumption, the two values are multiplied. If the product is constant for all the value pairs, inverse-proportionality is present, if not, it has to be checked if inverse-proportionality with x^2 is present, i.e. whether the product of photo-electric current and the square of the distance
is constant, etc. Enter all the required values in table 2 and calculate the product. Continue doing this until you obtain an (approximately) constant product.

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