What is the guiding principle behind electric exposure meters?

Problem
Investigate the behavior of a photo diode when exposed to light.

Equipment

Plug-in board	06033.00	1
Lamp holder E10	17049.00	1
Filament lamp, 6 V/0.5 A, E10, 1 pc.	35673.03	(1)
Filament lamp, 12 V/0.1 A, E10, 1 pc.	07505.03	(1)
Photo diode	39119.01	1
Wire building block	39120.00	4
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 25 cm, blue	07360.04	1
Connecting cables, 50 cm, red	07361.01	1
Connecting cables, 50 cm, blue	07361.04	1
Multi-range meter	07028.01	1
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

Set-Up and Procedure
— Set up circuit as shown in Fig. 1.
Select measurement range of 50 μA.
Note: The photo diode should only be plugged into the plug-in board just far enough that there is a good electrical contact, leaving enough room for it to be exposed to light at short distances.

— Switch on power supply unit. Beginning at 11 grid spaces GS (1 GS = the distance between two neighboring sockets), reduce the distance between the photo diode and the filament lamp in increments of one GS, measuring short-circuit current I_S for each increment. Enter measurements in Table 1. Stop measurement series if the meter registers maximum value.

— Instead of 6 V filament lamp, use 12 V filament lamp, starting 6 GS away from the photo diode. Select 12 V~ on power supply unit. Measure current and note under (1).

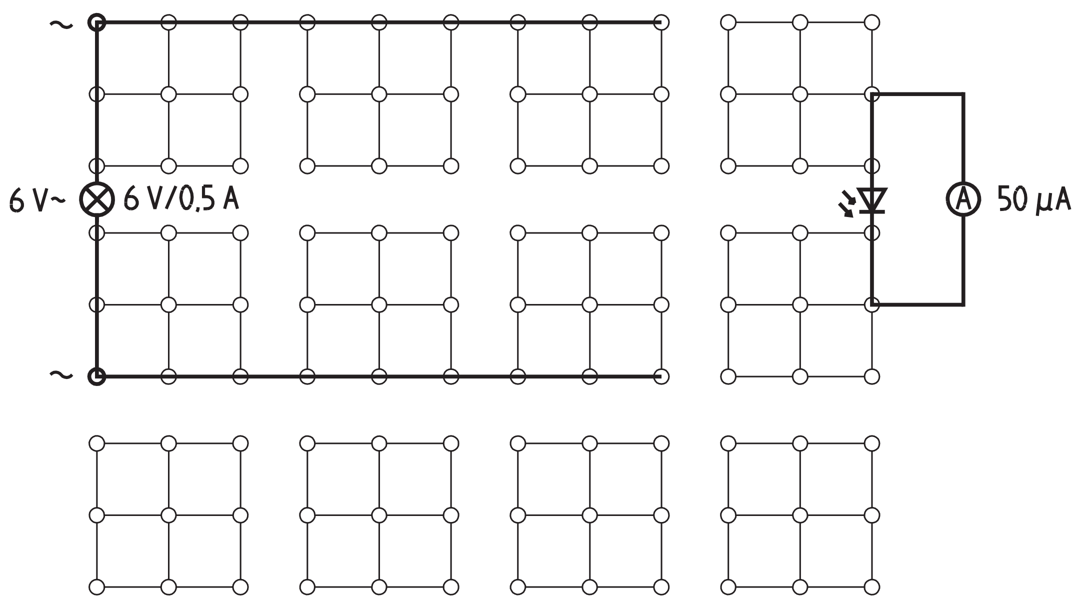
— Switch power supply unit off.

Measurement Results
Table 1

Distance d in GS	Current I_S/μA	$\frac{1}{d^2}$
11		
10		
9		
8		
7		
6		
5		
4		
3		

(1) I_S = ...

Fig. 1



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Evaluation

1. Graph short-circuit current I_S of the photo diode as a function of distance d (in GS) of the light source from the photo diode (Fig. 2).
2. Calculate the values for $1/d^2$ and enter them in Table 1. Graph short-circuit current as a function of $1/d^2$ (Fig. 3).
3. What conclusions can be drawn from the two graphs?
   Note: Consider how the illumination of a surface illuminated by a point light source varies with a change in the distance between the surface and light source.

4. How could an exposure meter be constructed, in principle, using a photo diode?

5. What is the ratio between the luminous intensity of the filament lamps used in this experiment?

Fig. 2

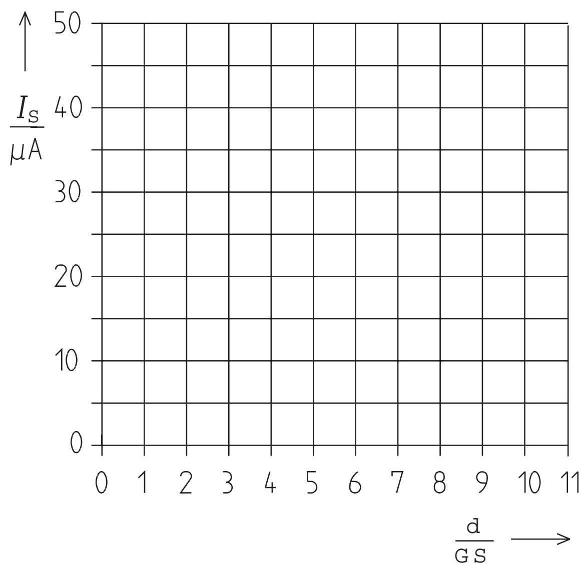
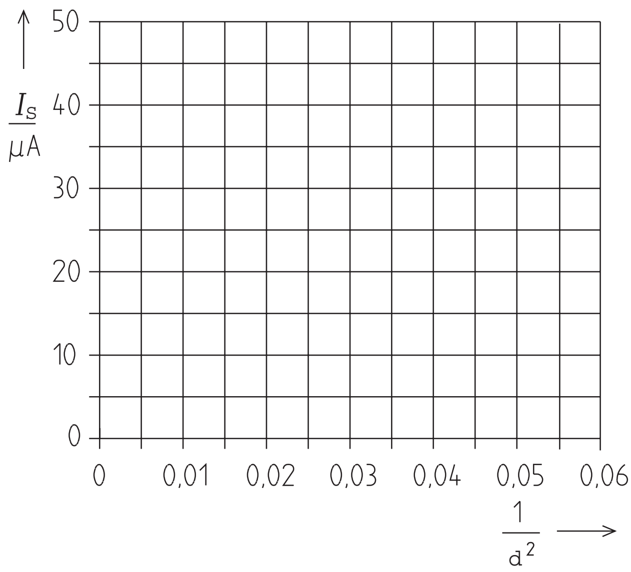


Fig. 3



(What is the guiding principle behind electric exposure meters?)

Photo diodes are specially constructed so that light can shine on the barrier layer of the pn junction. The photo energy creates pairs of charge carriers enabling a photocurrent. The photocurrent is proportional to the light intensity, meaning photo diodes are quite suitable for optical measurements. There is no linear relationship for the photovoltage created by the light. For this reason, photo diodes are often used as light-dependent current sources in short-circuit operation. Connecting voltage only increases the photocurrent minimally.
For the students to see the linear nature of photocurrent as a function of light intensity, they must understand the relationship between the distance between a point light source and the surface being illuminated and the light intensity. A good understanding of this concept will allow them to interpret Fig. 3 properly. Of course, you may want to limit yourself to a half-quantitative description and leave Fig. 3 out altogether.

Notes on Set-Up and Procedure
To ensure defined and uniform changes in distance, we suggest moving the filament lamp towards the photo diode using the grid spaces on the plug-in board. At short distances, the photo diode will be in the shadow of the plug-in component for the filament lamp. Therefore, the photo diode should only be plugged into the plug-in board just far enough to establish a good electrical contact.

Make sure there is as little scattered light from the room lighting shining on the photo diode as possible. Too much scattered lighting leads to errors in the measurements.

Measurement Results
Table 1

Distance d in GS	Current $I_S/\mu A$	$\frac{1}{d^2}$
11	5	0.0083
10	6.5	0.010
9	7.5	0.012
8	10	0.0156
7	13	0.020
6	18	0.028
5	25	0.040
4	36	0.062
3	>50	0.111

(1) $I_S = 12\ \mu A$

Fig. 2

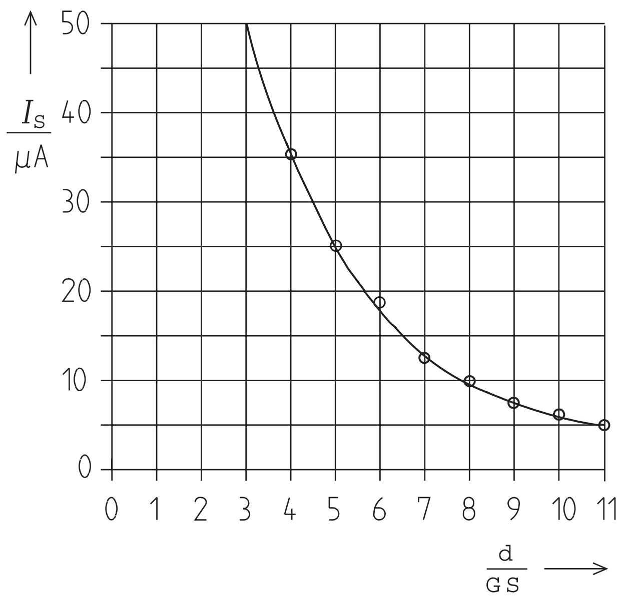
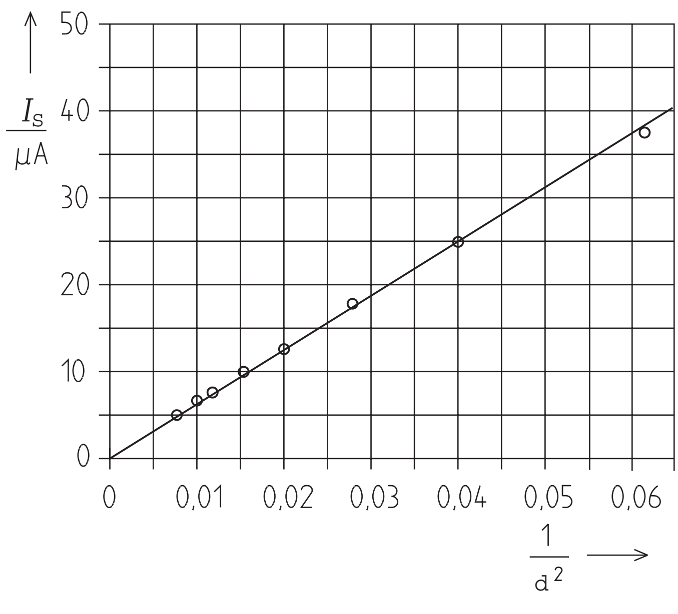


Fig. 3



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Evaluation

1. See Fig. 2.
2. See Table 1, right-hand column, and Fig. 3.
3. Fig. 2 shows that short-circuit current I_S increases as the distance between the photo diode and light source is decreased.
   It is apparent from Fig. 3 that photocurrent is proportional to light intensity because the relationship between distance d and light intensity E for surfaces illuminated by a point light source is $E \sim 1/d^2$
4. An exposure meter could be constructed from a photo diode (or a photoelement) and a sensitive current meter. With a known luminous intensity from the light source, the scale of the meter can be divided into values for light intensity.
5. The two filament have different luminous intensities. The 6 V/0.5 A filament lamp shines more brightly. The luminous intensities are related in the same way as

$$I_{S1} : I_{S2} = 18 : 12 = 3 : 2.$$