ES - 265

OPERATING INSTRUCTIONS

FOR

PLANCK'S CONSTANT BY SPECTROMETER AND PHOTO VOLTAIC CELL

OMEGA TYPE ES-265

Manufacturer & Exporter:

OMEGA ELECTRONICS

MARKETING DIVISION:
B-28, FATEH SINGH SCHEME
OPP. RAJPUTANA PALACE SHERATON,
JAIPUR - 302006 (INDIA)
PHONE : 2375647, 2379223
FAX : 091-141-2204481

WORKS:
28 E & F, MALVIYA INDUSTRIAL AREA,
JAIPUR - 302 017 (INDIA)
PHONE : 2751136, TELEFAX : 2751559

EMAIL : info@omegaelectronics.net
jaipur.omega@gmail.com
www.omegaelectronics.net

OMEGA TYPE ES-265 Experimental Set-Up has been designed specifically to study of Planck's Constant by Spectrometer and Photo Voltaic cell. The set-up consists of Spectrometer, Digital Nanoammeter, Prism, Photovoltaic cell, Power supply etc.

The set up is complete in all respects and requires no other apparatus. Practical experience on this set up carries great educative value for Science and Engineering Students.

OBJECT

1. Determination of Planck' s Constant by Spectrometer and Photo voltaic cell.

FEATURES

The complete Experimental Set-up consists of the following :

1. **SPECTROMETER STANDARD** : 6" dia circle reading 30seconds, with a long arm in place of Telescope fitted with double convex lens 50mm dia, focal length 40cm on one end and photo voltaic cell with width adjustable slit drum type on the other end. The distance between lens and photo voltaic cell can be adjusted for better focussing. Prism table is provided with three leveling screws and is engraved with concentric rings and lines. The scales and verniers are of stainless steel and are machine divided.
2. **DIGITAL NANOAMMETER** :

Range	:	100nA, 1μA, 10μA, 100μA.
Accuracy	:	±0.25% for all ranges
Resolution	:	0.1nA, 1.0nA, 10nA, 100nA.
Input Resistance	:	25Ω, 2.5Ω, 0.25Ω, 0.025Ω.
Display	:	3½ digit 7segment LED (12.5mm height) with auto polarity and decimal indication.
Input	:	Through amphenol connector.
Power Supply	:	220V ± 10%, 50Hz.

3. **PRISM** : Optically worked with two faces polished, Equilateral, size 38mm x 38mm.
4. **POWER SUPPLY** : 0-6V DC at 3A, IC regulated, continuously variable and short circuit protected power supply with coarse and fine voltage controls with two Digital Panel Meters (DPM) of 3½ digit one of 19.99 volt D.C. and other of 19.99 Amp. D.C.

5.Photo voltaic cell with width adjustable slit Durm type on stand.

6.Incandescent bulb with house on stand.

7.Double convex lens (50mm dia. and F.L. 10cm) with holder on stand.

THEORY AND FORMULA USED

The Planck's radiation formula is

$$E_\lambda d_\lambda = \frac{C_1 \times \lambda^{-5}}{\left(e^{C_2/\lambda T} - 1\right)} d\lambda \qquad (1)$$

here

$$C_1 = 8\pi hc$$

$$C_2 = \frac{hc}{k}$$

The formula therefore becomes

$$E_\lambda d_\lambda = \frac{c_1}{\lambda^5} \cdot \frac{1}{\left(e^{C_2/\lambda T} - 1\right)} d\lambda \qquad (2)$$

When we substitute the values of h, c, k, the values of wavelength λ and the temperature T of the filament, we will be in a position to find the exponent., h, c & k are std. constants & the values are

$h = 6.626 \times 10^{-34}$ Joule.Sec.

$c = 3 \times 10^{8}$ m/sec.

$k = 1.38 \times 10^{-23}$ Joule/^{0}K

Let λ be equal to 7500×10^{-10}m for the red wavelength.

& T = about 4000^{0}K

When we substitute the above values then the exponent becomes very large so the second term (1) can be neglected & the Planck's radiation formula becomes.

$$E_\lambda d_\lambda = \frac{c_1}{\lambda^5} \cdot \frac{1}{\left(e^{C_2/\lambda T}\right)} d\lambda = \frac{c_1}{\lambda^5} \times e^{-C_2/\lambda T} \cdot d\lambda \tag{3}$$

This is called Wien's formula (Wien's Radiation Formula). This is also Called Wien's Distabution Formula.

This we are going to verify & determine the value of Planck's constant from (3) we see that if λ is fixed for the red region of the spectrum from the lamp, C_1/λ^5 is a constant say A and in the exponent term C_2/λ is also a constant say β then Wien's radiation formula becomes

$$E_\lambda d_\lambda = A \cdot e^{-\beta/T} \cdot d_\lambda \tag{4}$$

$E_\lambda d_\lambda$ is the quantity of Energy (in a narrow wavelength region) radiated per sec. per unit area of the filament, considered to be a black body. $E_\lambda d\lambda$ is also related in the experiment, to the reading of the nanoammeter with a proportionality constant.

Therefore ,from (4), we have

$$\log_e E_\lambda d_\lambda = \log_e A - \frac{\beta}{T} \tag{5}$$

$$\text{Also, } \log_{10} E_\lambda d_\lambda = \log_{10} m\theta = \log_{10} m + \log_{10}\theta \tag{6}$$

from (5) & (6)

$$\log_{10} A - \frac{B}{2.303} \times \frac{1}{T} = \log_{10} m + \log_{10}\theta$$

or

$$\log_{10}\theta = \log_{10} A - \log_{10} m - \frac{B}{2.303} \times \frac{1}{T}$$

$$= \log_{10}\frac{A}{m} - \frac{B}{2.303} \times \frac{1}{T}$$

$$\log_{10}\theta = \log_{10} D - \frac{B}{2.303} \times \frac{1}{T}$$

We assume $\frac{A}{m} = D$

on plotting $\log_{10}\theta$ along Y-axis & 1/T along X-axis we can write

$$Y = C - m'x$$

m' = slope of the graph

A straight line proves the Wien's radiation law. The slope will measure the value of Planck's constant (h) m' is the slope given by

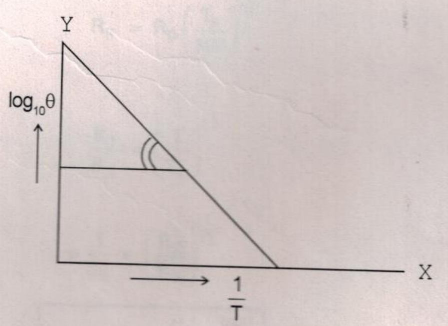


Fig.1

$$m' = \frac{B}{2.303} = \frac{c_2}{\lambda \times 2.303} = \frac{hc}{k\lambda \times 2.303}$$

$$\boxed{h = \frac{m'k\lambda \times 2.303}{c}} \qquad (7)$$

Temperature T can be obtained by using Langmuir's Formula.

$$\frac{R_T}{R_0} = \left(\frac{T}{T_0}\right)^{1.2} \qquad (8)$$

Where

R_T = Resistance of bulb filament at particular temperature (T)

R_0 = Resistance of bulb filament at 0°C temperature (T_0)

and at room temperature

$$\frac{R_R}{R_0} = \left(\frac{T_R}{T_0}\right)^{1.2} \qquad (9)$$

where R_R = Resistance of bulb filament at room temperature (T_R)

At Draper point (T_D)

$$\frac{R_D}{R_0} = \left(\frac{T_D}{T_0}\right)^{1.2} \qquad (10)$$

where R_D = Resistance of bulb filament at Draper point (T_D)

$T_D \cong 530^0C \cong 800^0K$

$T_0 = 0^0C = 273^0K$

The Draper point is the temperature at which the filament of the bulb just glows with dull red colour.

The difficulty arises when we have to find the resistance of the filament at room temperature which requires that the filament SHOULD NOT GLOW and must remain cold (at the room temperature). Since this is a difficult task to realize in practice, we are modifying the method slightly.

In practice we find the resistance of the tungsten filament at the DRAPER POINT ($\cong 527^0C = 800^0K$)

Dividing eq^n (9) by eq^n(10)

$$\frac{R_R}{R_D} = \left(\frac{T_R}{T_D}\right)^{1.2}$$

$$R_R = R_D\left(\frac{T_R}{800}\right)^{1.2} \qquad (11)$$

and dividing eq^n (8) by eq^n (9)

$$\frac{R_T}{R_R} = \left(\frac{T}{T_R}\right)^{1.2}$$

$$\Rightarrow \frac{T}{T_R} = \left(\frac{R_T}{R_R}\right)^{\frac{1}{1.2}}$$

$$\boxed{\Rightarrow T = T_R\left(\frac{R_T}{R_R}\right)^{0.833}} \qquad (12)$$

PROCEDURE

Resistance of filament at Draper Point

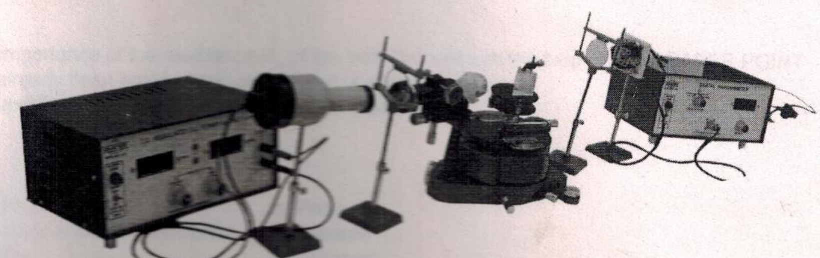
1. Connect the leads of incandescent bulb with power supply.
2. Now, switch on the circuit starting with a low current, raise the current till the filament just shows a glow. (keeping the bulb in a covered enclosure helps judging the stage). Measure I_D and V_D, next reduce the current till the glow just ceases. Measure I_D and V_D again. Thus, get the mean $V_D/I_D = R_D$ for the Draper point.

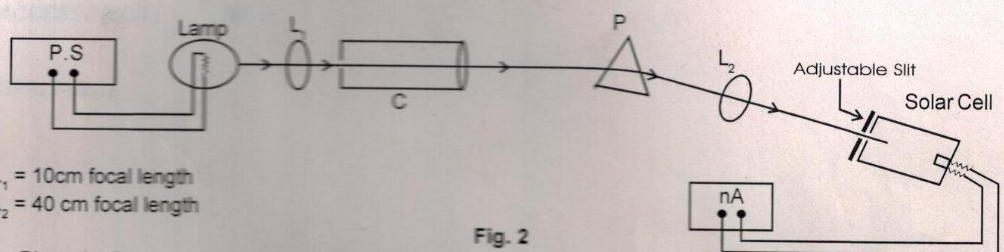
By using eq. (11) we get R_R

$$R_R = R_D \left(\frac{T_R}{800}\right)^{1.2}$$

Measurement of Deflection of Nanoammeter and Temperature of Filament

1. Place the Incandescent bulb with house on stand and duble convex lens with holder on stand in one straight line as shown in diagram.





L_1 = 10cm focal length
L_2 = 40 cm focal length

Fig. 2

2. Place the Prism on the Prism table with its refracting angle A towards the collimator.
3. Focus the light of incandescent bulb on the slit of collimator with the help of convex lens.
4. See the spectrum with double convex lens.
5. Set slit in such a way that only red region of spectrum falls on photovoltaic cell
6. And note down the corresponding reading of voltmeter, currentmeter of power supply and Nanoammeter connected with photocell.
7. Now by the varying the Voltage of power supply take the reversal sets of readings of corresponding meters and note down in observation Table.
8. Now calculate the temperature of filament for different values of filament resistance at different heating currents by using eq. (12).
9. Plot the graph between $\log_{10} \theta$ & $1/T$.
10. Calculate the slope of the graph then calculate the value of Planck's constant by using eq. (7).

OBSERVATIONS

R_R = --------Ω

Table 1

Sr. No.	A (Amp.)	V (Volt)	$R_T = \frac{V}{A}$ (Ω)	$T = T_R \left(\frac{R_T}{R_R}\right)^{0.833}$ °K	Deflection of Nano meter θ	$\frac{1}{T}$	$\log_{10} \theta$
1.							
2.							
3.							
4.							

NOTE : 1. The importance of the resistance R_R of the bulb filament with the help of due DRAPER POINT has already been emphasized on page no. 4 of the Theory.

2. This experiment must be performed in dark room

REFERENCES

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04 Modern Physics : Richtmyer & Kennard

ACCESSORIES : Nil

GPA27-02-12