3. Structure

A schematic diagram of the apparatus is shown in Fig. 4. The apparatus consists of a light source, a light receiving phototube, a DC amplifier, and five color filters. The light source and the receiving unit are installed on the base rail, and their distance can be adjusted and read from the scale.

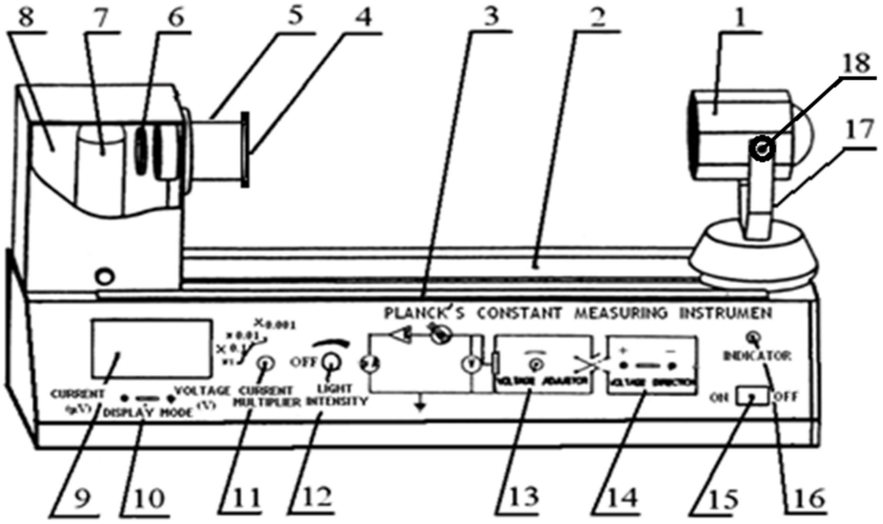


Figure 4 Schematic diagram of apparatus

1—Light source	2—Base rail	3—Scale (length= 400 mm)
4—Receiver cover (or filter)	5—Receiver tube	6—Focusing lens
7—Vacuum phototube	8—Receiver box	9—Digital meter (V or I)
10—Display mode switch (V or I)	11—Current multiplier	12—Light intensity adjust
13—Accelerating voltage adjust	14—Voltage polarity switch	15—Power switch
16—Power indicator	17—Locking screw	18—Fixing knob

4. Setup and Adjustment

Note: Upon receipt of the apparatus, unscrew the cover plate of receiver box (8) and remove protective sponge. Make sure the phototube is completely unobstructed and re-screw the cover plate.

Warning: Please handle the phototube and the light bulb with care, as they are very fragile!

1) Setup

a. Place the instrument on a secure table, make sure receiver tube (5) is blocked with cover (4), turn on the power, set light intensity adjustor (12) at moderate light level, slide light source (1) to 250 mm position, and tighten the lock screw (17). If the lamp is not turned on, check if the lamp bulb slips off the mount.

b. Adjust the tilt of the light source to let light illuminate straightly onto the phototube.

2) Electrical adjustment

a. Set display mode switch (10) to voltage display and adjust accelerating voltage adjustor (13) to get a stable voltage reading of ± 15 V.
b. Set display mode switch (10) to current display and keep the phototube covered while adjusting current multiplier (11) to choose among "×1", "×0.1", "×0.01", or "×0.001" to ensure the dark current is less than 0.003 μA.
c. Change light intensity adjustor (12) to view different light intensity levels among strong, moderate, weak, or off.
d. Optimal conditions: light should shine on the central area of the phototube's cathode plate rather than the anode, and maximum current should be observed. These conditions have been achieved in factory. If alignment is needed, open the top plate of receiver box (8) when the lamp is on, the image of the lamp can be seen on the cathode plate, adjust lamp location and tilt to bring the image to the central area of the plate (this should be performed by an experienced technician or instructor).

5. Experimental Procedures

1) Slide light source (1) to 250 mm position, turn on the power, pre-heat the system for 5 minutes, and set current multiplier (11) at "×1" position.
2) Place the red color filter (635 nm) onto receiver tube (5), set light intensity adjustor (12) at moderate light level, voltage polarity switch (14) at "+", current multiplier (11) at "×1" or "×0.1", and turn accelerating voltage adjustor (13) to gradually increase the photocurrent to saturation, and record the corresponding voltage. Use display mode switch (10) to toggle between current or voltage display.
3) Block the receiver tube by hand, the photocurrent should disappear at once; remove the hand, the photocurrent should reappear again, indicating that the photocurrent is formed very quickly (not exceeding 10^{-9} s).
4) Change the distance (R) between light source (1) and vacuum phototube (7), record the distance value (R) with corresponding photocurrent (I), and draw the I - $1/R^2$ curve. A straight line should be obtained.
5) Set light intensity adjustor (12) at strong light level, slide the light source to 300 mm position, voltage polarity switch (14) at "-", display mode switch (10) at current display, accelerating voltage to 0 V, and set current multiplier (11) at "×0.001". Adjust the accelerating voltage to decrease the photocurrent to zero, write down the accelerating voltage value for 635 nm wavelength.
6) Repeat step 5) for each of the filters, and record the voltage value for each wavelength.
7) Convert the five wavelengths into frequencies ($\nu=c/\lambda$ where $c=3\times10^8$ *m/s* is the speed of light), plot accelerating voltage versus frequency, calculate the slope of the plotted line by means of least-square curve fitting, and derive Planck's constant using Eq. (5).

Note: 1. To minimize measurement error, avoid or minimize stray light to the sensor.

2. To minimize the effect of dark current, the relationship curve between accelerating voltage and dark current should be acquired initially by measuring accelerating voltage with corresponding photo current with the receiver tube being blocked. Then, the acquired dark current should be used as the "zero" photo current when measuring the cutoff voltage in the experiment. For example, in the experiment, if the cutoff voltage of a specific filter is pre-determined at -0.5 V corresponding to real zero current output, and the dark current at this voltage is found 0.001 μA as previously measured, the accelerating voltage should be slightly adjusted until the

photo current changes to 0.001 μA from 0 μA. In other words, the accelerating voltage corresponding to 0.001 μA should be taken as the cutoff voltage, rather than the accelerating voltage corresponding to zero current.

Warning: the Halogen Tungsten lamp can become very hot if turned on over a few minutes, so avoid touching the lamp or the lamp housing with bare hands!

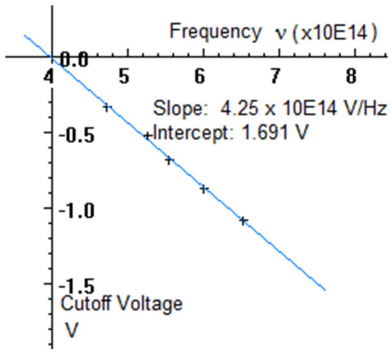
6. Example of Data Recording and Processing

Note: Following data are for reference purpose only, not the criteria for apparatus performance:

Cutoff voltages at various wavelengths are recorded in the table below:

Wavelength (nm)	460	500	540	570	635
Frequency (10^{14}Hz)	6.52	6.00	5.56	5.26	4.72
U_s (V)	**-1.08**	**-0.87**	**-0.68**	**-0.52**	**-0.33**

The Frequency – Cutoff Voltage relationship is plotted as following:



Planck constant is calculated as 6.803×10^{-34} J.s. Error is 2.7%.