Manual for Planck's Constant Measuring Apparatus

Model PC-101

July 4, 2009

User's Manual

PLANCK'S CONSTANT MEASURING SET-UP

Model: PC-101

ISO 9001 : 2000
Certified Company

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It was observed as early as 1905 that most metals under influence of radiation, emit electrons. This phenomenon was termed as photoelectric emission. The detailed study of it has shown.

1. That the emission process depends strongly on frequency of radiation.
2. For each metal there exists a critical frequency such that light of lower frequency is unable to liberate electrons, while light of higher frequency always does.
3. The emission of electron occurs within a very short time interval after arrival of the radiation and member of electrons is strictly proportional to the intensity of this radiation.

The experimental facts given above are among the strongest evidence that the electromagnetic field is quantified and the field consists of quanta of energy E= hν where ν is the frequency of the radiation and h is the Planck's constant. These quanta are called photons.

Further it is assumed that electrons are bound inside the metal surface with an energy eϕ, where ϕ is called work function. It then follows that if the frequency of the light is such that

$$h\nu > e\phi$$

it will be possible to eject photoelectron, while if hν<eϕ, it would be impossible. In the former case, the excess energy of quantum appears as kinetic energy of the electron, so that

$$h\nu = \frac{1}{2}mv^2 + e\phi \qquad (1)$$

which is the famous photoelectrons equation formulated by Einstein in 1905.

The energy of emitted photoelectrons can be measured by simple retarding potential techniques as is done in this experiment. Retarding potential at which the photo current stop, we call it stopping potential V_s and is used to measure kinetic energy of electrons E_e, we have,

$$E_e = \frac{1}{2}mv^2 = eV_s \qquad \text{or} \qquad V_s = \frac{h}{e}\nu - \phi$$

So when we plot a graph V_s as a function of ν, the slope of the straight line yields $\frac{h}{e}$ and the intercept of extrapolated point ν=0 can give work function ϕ.

THE APPARATUS CONSIST OF THE FOLLOWING:

1. **Photo Sensitive Device**: Vacuum photo tube.
2. **Light source**: Halogen tungsten lamp 12V/35W.
3. **Color Filters**: 635nm, 570nm, 540nm, 500nm & 460nm.
4. **Accelerating Voltage** : Regulated Voltage Power Supply

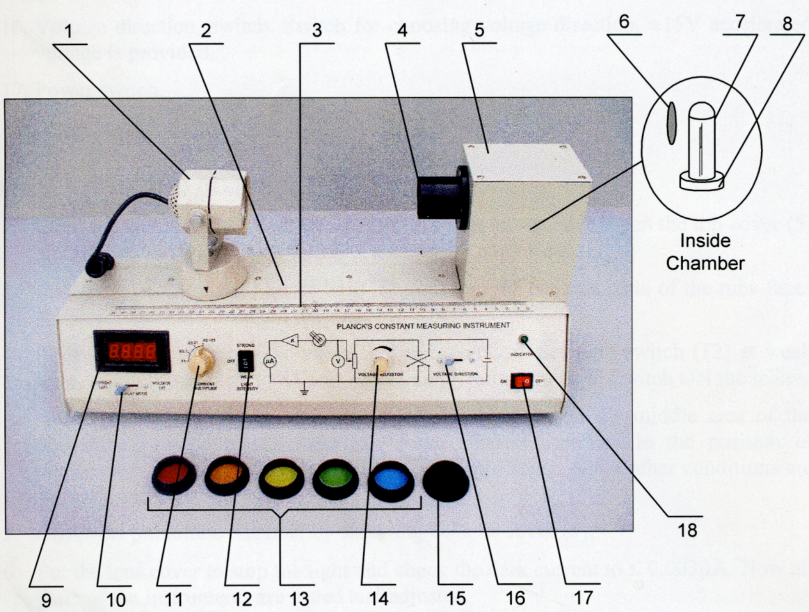
Output	: ± 15 V continuously variable through multi-turn pot
Display	: 3 ½ digit 7-segment LED
Accuracy	: ±0.2%

5. **Current Detecting Unit** : Digital Nanoammeter
   It is high stability low current measuring instrument

Range	:	X 1μA, 0.1μA, 0.01μA & 0.001μA with 100% over ranging facility
Resolution	:	1nA at 0.001μA range
Display	:	3½ digit 7-segment LED
Accuracy	:	±0.2%

6. **Power Requirement**: 110V ± 10%, 60Hz.
7. **Optical Bench:** The light source can be moved along it to adjust the distance between light source and phototube scale length is 400 mm. A drawtube is provided to install color filter; a focus lens is fixed in the back end.

STRUCTURE



1. Light Source, 12V/35W halogen tungsten lamp.
2. Guide. Move the light source along it, the distance between light source and receiving dark box can be adjusted.
3. Scale. 400mm total length. The center of the vacuum phototube is used as zero point.
4. Drawtube. The forepart is used for installing color filter; a focus lens is fixed in the back end.
5. Cover. Used to cover chamber containing Phototube.
6. Focus lens. Make a clear image of light source on the cathode area of phototube.
7. Vacuum Phototube. The sensitive component.

8. Base for holding the Phototube
9. Digital Meter. Show current (μA), or voltage (V).
10. Display mode switch. For switching the display between voltage and current mode.
11. Current Multiplier.
12. Light Intensity Switch. Switch for choosing light intensity. Up is of strong, middle is of off; down is for weak.
13. Filter set. Five pieces
14. Lens Cover. (For protecting the phototube from stray light during ideal period)
15. Accelerate voltage adjustor. Knob for adjusting accelerate voltage.
16. Voltage direction, switch. Switch for choosing voltage direction. ±15V accelerated voltage is provided.
17. Power switch.
18. Power indicator.

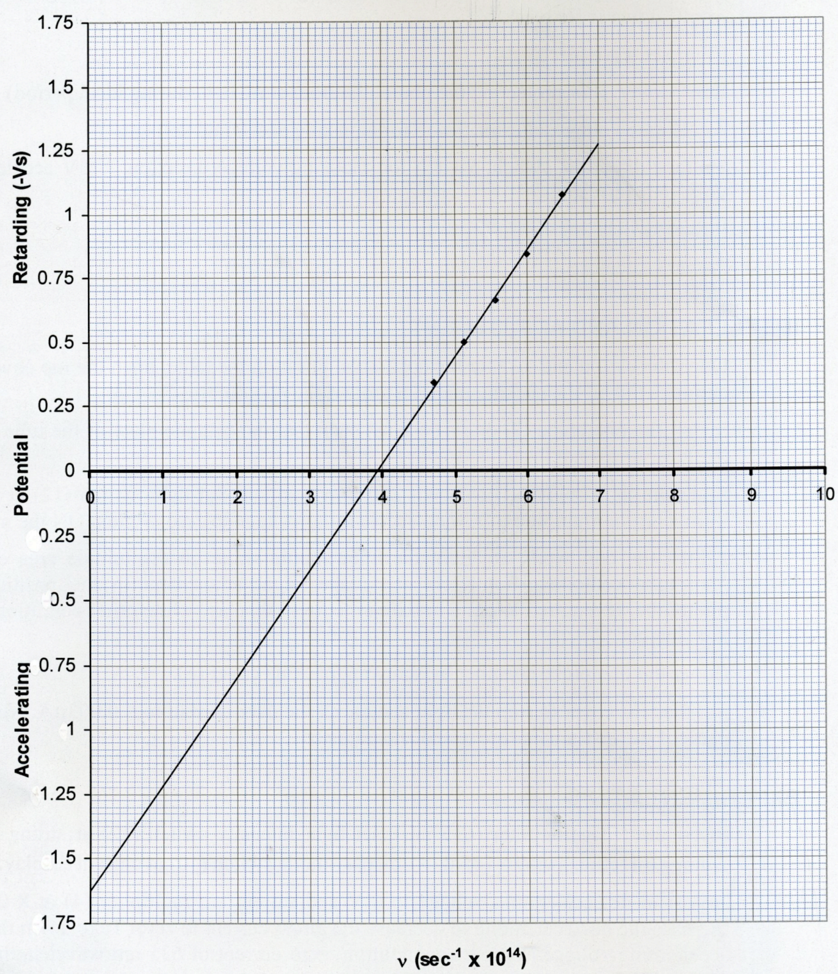
INSTALLATION AND ADJUSTMENT

1. Open the carton and takeout the apparatus. Put it on the table, open the top cover (5) and take out all the packing material around the phototube.
2. Install the phototube (7) on its base (8) such that the cathode plate of the tube faces the lens, if it is not installed or loose.
3. Slide the light source (I) to about 250 mm position. Set light switch (12) at weak light, current multiplier to X1 and accelerating voltage to zero. Switch ON the mains.
4. Adjust the best work situation: the light should shine on the middle area of the phototube cathode plate. Users can make slight adjustment in the position of phototube, if required to get a maximum current display, while other conditions are not changed.
5. Cover the phototube chamber by screwing back its cover (5).
6. Put the lens cover to stop the light and check the dark current to ≤ 0.003μA. Now all parts of the instruments are tested and adjusted.

EXPERIMENT STEPS

1. Insert the red color filter (635 nm), set light intensity switch (12) at strong light, voltage direction switch (14) at `-‘, display mode switch (10) at current display.
2. Adjust to de-accelerating voltage to 0 V and set current multiplier (4) at X 0.001. Increase the de-accelerating to decrease the photo current to zero. Take down the de-accelerating voltage (V_s) corresponding to zero current of 635 nm wavelength. Get the Vs of other wave lengths, the same way.

PLANCK'S CONSTANT MEASURING APPARATUS



Typical Observations & Calculation:

Observations:

S. No	Filters	ν (sec^{-1} x 10^{14})	Stopping Voltage (V)
1	Red (635 nm)	4.72	- 0.34
2	Yellow I (585 nm)	5.13	- 0.50
3	Yellow II (540 nm)	5.56	- 0.66
4	Green (500 nm)	6.00	- 0.84
5	Blue (460 nm)	6.50	- 1.07

Calculations

Planck's Constant: $h = e\frac{\Delta V_s}{\Delta \nu}$

Where e is the charge of electron

By putting the value of ΔV_S & $\Delta\nu$ from graph

$$h = 1.602 \times 10^{-19} \times \frac{0.825}{2.00 \times 10^{14}}$$

$$= 1.602 \times 10^{-19} \times 0.413 \times 10^{-14}$$

$$= 6.61 \times 10^{-34} \text{ Joules sec.}$$

From Graph 1 intercept at $\nu = 0$ the value of

$\phi = 1.625$ V

Compared with accepted value of $h = 6.62 \times 10^{-34}$ Joules. sec. the results are well within accepted error range.

PRECAUTIONS

1. This instrument should be operated in a dry, cool indoor space.
2. Phototube particularly should not be exposed to direct light, particularly at the time of installation of phototube; the room should be only dimly lit.
3. The instrument should be kept in dust proof and moisture proof environment, if there is dust on the phototube, color filter, lens etc. clean it by using absorbent cotton with a few drops of alcohol.
4. The color filter should be stored in dry and dust proof environment.
5. After finishing the experiment remember to switch off power and cover the drawtube (4) with the lens cover (15) provided. Phototube is light sensitive device and its sensitivity decreases with exposure to light and due to ageing.