The Photoelectric Effect

University physics center of UEST

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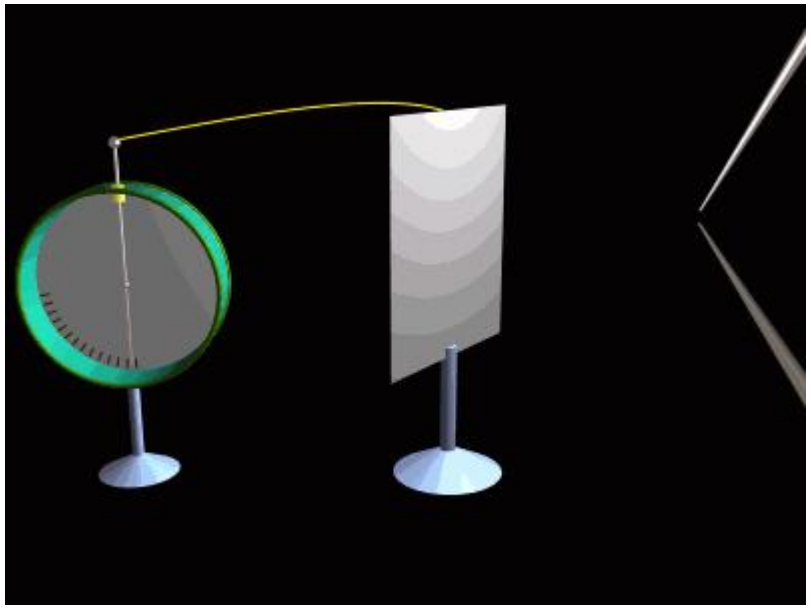
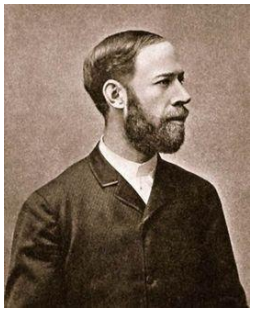
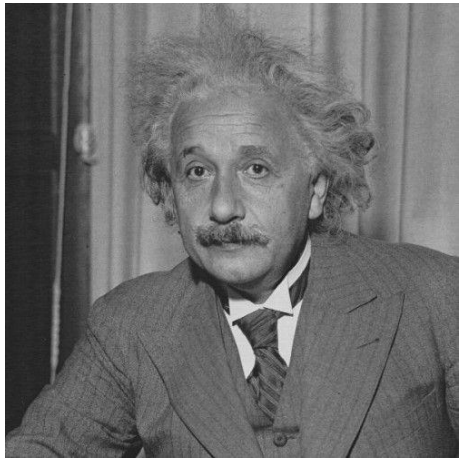
1.1 Particle Property of Light: Photoelectric Effect



（Heinrich Rudolf Hertz，1857-1894）



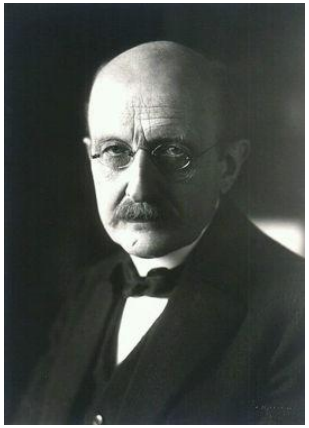
1887 found by Hertz



Einstein put forward the correct theoretical mechanism

（Albert Einstein，1879-1955）

1.2 Planck 's Constant



（Max Planck，1858－1947）

- **Only the assumption that the emission and absorption of electromagnetic waves is carried out in one part, the results of the calculation can be consistent with the test results.**
- **The Concept of Energy Quantum**

$$E = h\nu$$

h=6.62559×10^{-34}J·s

2. aim

- By testing the basic characteristics of photoelectric effect curve, to further understand and understand the quantum of light;
- Determine the five different frequencies of the reverse cut-off voltage, cut-off voltage and frequency linear relationship, find the "red limit" frequency;
- Verify Einstein optoelectronic equation, find Planck constant.

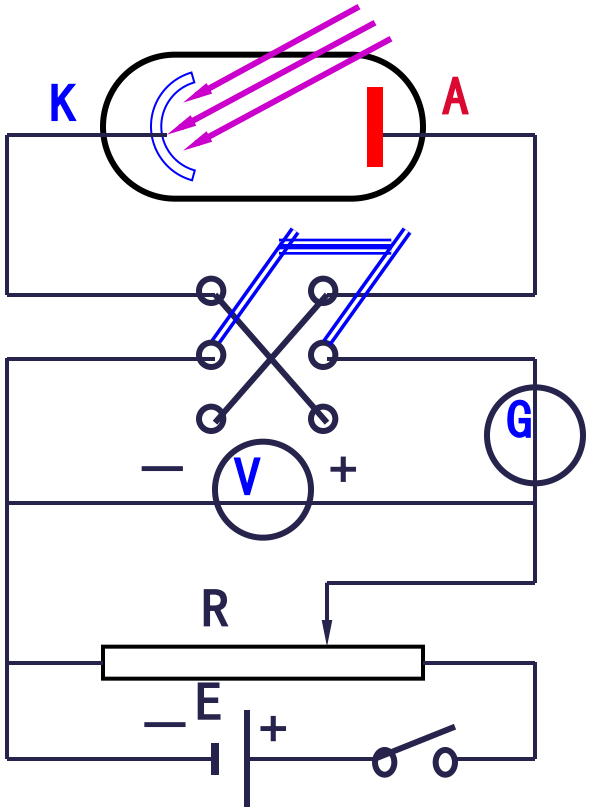
3. principle

3.1 phenomena and concepts

Photoelectric effect: light irradiation to the metal surface, there is the phenomenon of electrons from the metal surface to escape.

Photo-electron: runaway electron。

Photo-current: photo electron run from K to A, form the photo current in the circuse。

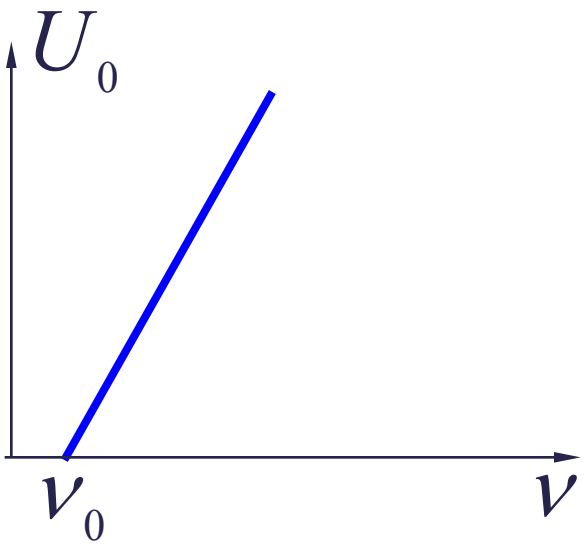


experimental diagram

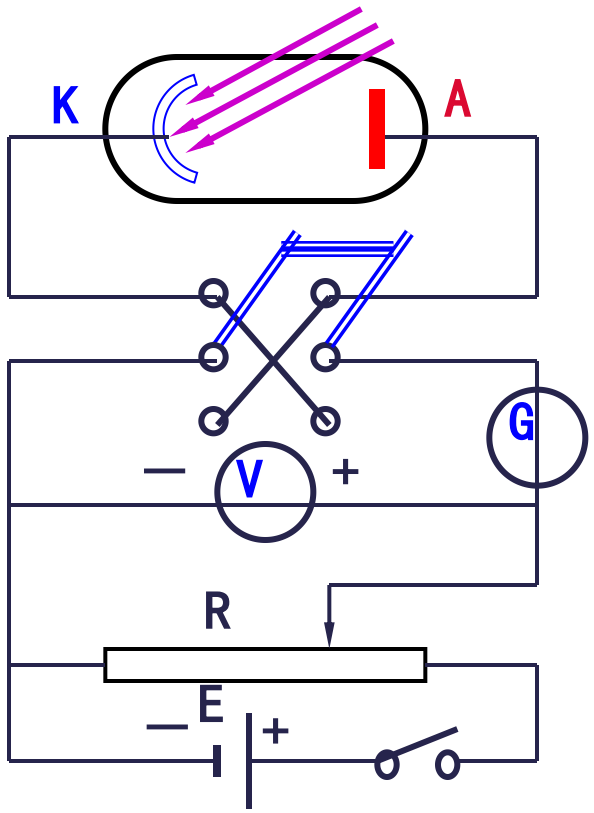
3.2 Experimental law Ⅰ

(1) When $v>v_0$（Cut-off frequency）occurs, related with the cut-off frequency and material, but has nothing to do with the incident light intensity.

(2) Cut off voltage U_0 linear relation with Incident light frequency



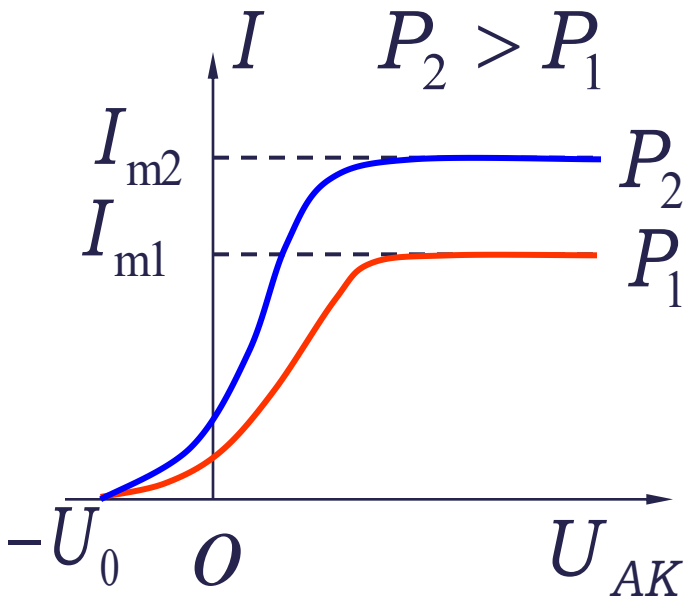
$U_0 \sim \nu$



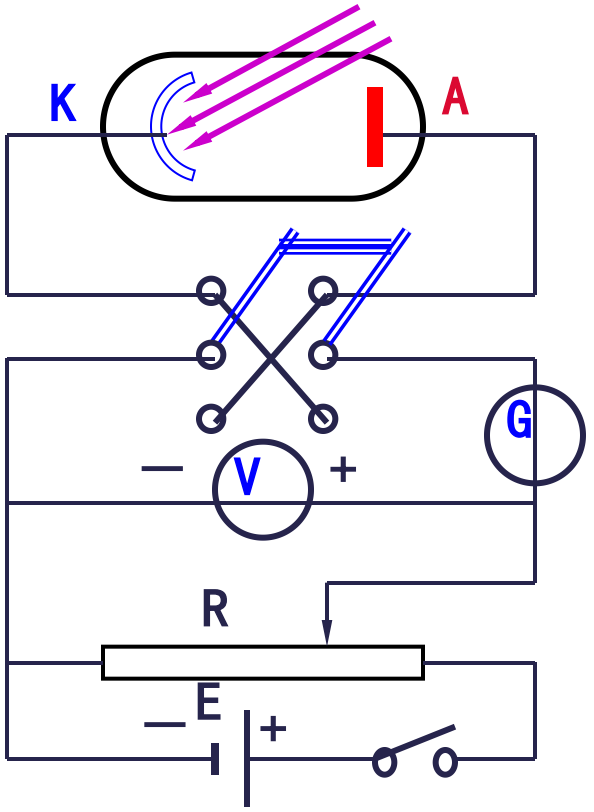
Experiment diagram

3.2 Experimental law II

(3) At the same frequency, the saturation photocurrent intensity I_m Proportional to the incident light intensity P。



The same frequency, different incident light intensity $I \sim U_{AK}$



Experiment diagram

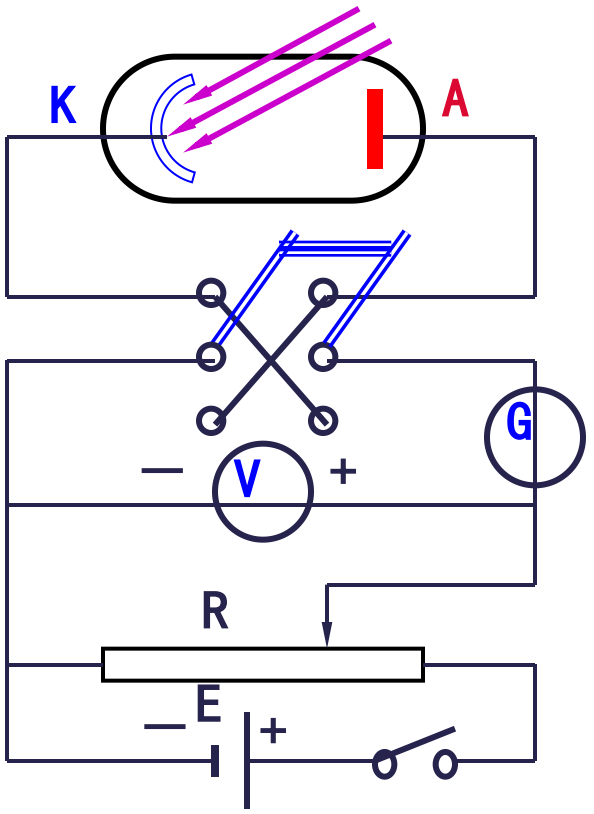
3.2 Experimental law Ⅲ

(4) Photoelectric effect is a transient effect. When the light is irradiated to the metal surface, almost immediately there is photoelectron escape. Time is less than 10^{-9}s。

Can not be used wave kinetic "forced vibration" to explain!

The solution: quantum mechanics!

Einstein



Experiment diagram

the successful interpretation of photoelectric effect experiments

3.3 Einstein 's Interpretation of Photoelectric Effect

Photon: A beam of light, consisting of photons, having a frequency of *v*.

The photon energy is *E=hv*。

Quantization of energy absorption: When the photon shines on the metal surface, an electron in a metal absorption and can only absorb the energy of a photon, without the accumulation of energy of time.

Energy Conservation: Electrons use part of the photon energy to overcome the metal surface for electron binding and work A, the rest of the electrons leave the metal surface after the kinetic energy.

Photoelectric effect equation：

$$\frac{1}{2}mV^2 = hv - \underbrace{A}_{\text{Escape energy}}$$

3.3 Einstein 's Interpretation of Photoelectric Effect

Discussion：

（1）when $h\nu<A$， $\nu<\nu_0$， electron can't escape from metal, no current

$$\frac{1}{2}mV^2 = h\nu - A = h\left(\nu - \frac{A}{h}\right) = h\left(\nu - \nu_0\right)$$

Red limit frequency

(2) $h\nu = \frac{1}{2}mV^2 + A$

$eU_0 = \frac{1}{2}mV^2$ (by measurement)

$$\Rightarrow U_0 = \frac{h}{e}\nu - \frac{A}{e}$$

Cut off voltage U_0 incident light frequency *v linear relationship*

The slope of the straight line to calculate the Planck constant h.

3.3 Einstein 's Interpretation of Photoelectric Effect

disscution:

(3) When the frequency is constant, the greater the incident light intensity P, the more the number of photons, the unit of time to produce the number of photoelectrons, the greater the intensity of saturated photocurrent.

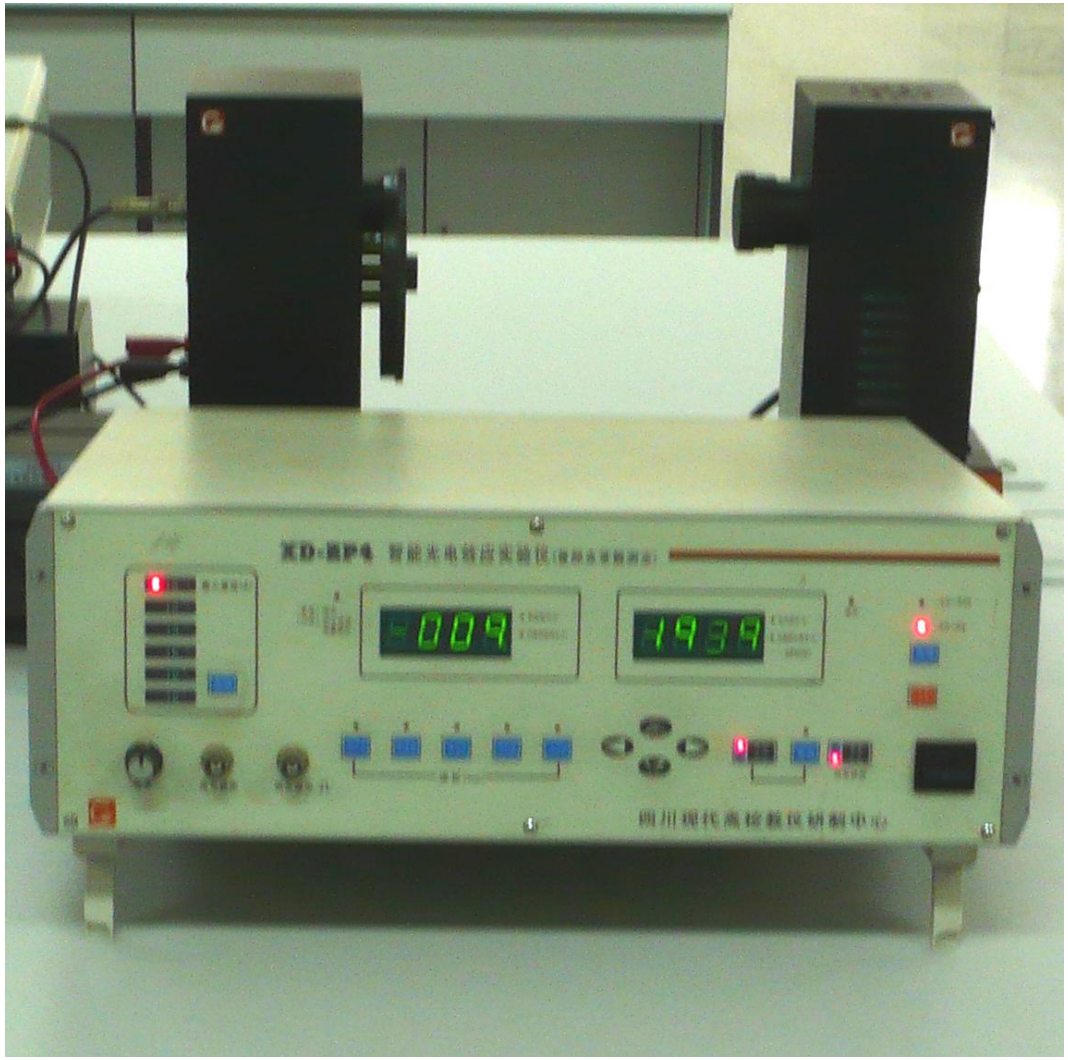
At the same frequency, the saturation current intensity I_m is proportional to the incident light intensity P.

(4) When the photon incident metal surface, a photon carrying energy $h\nu$ once for an electron all absorbed, if $\nu > \nu_0$, electrons immediately escape without time accumulation.

Photoelectric effect with instantaneous.

4. Equipment

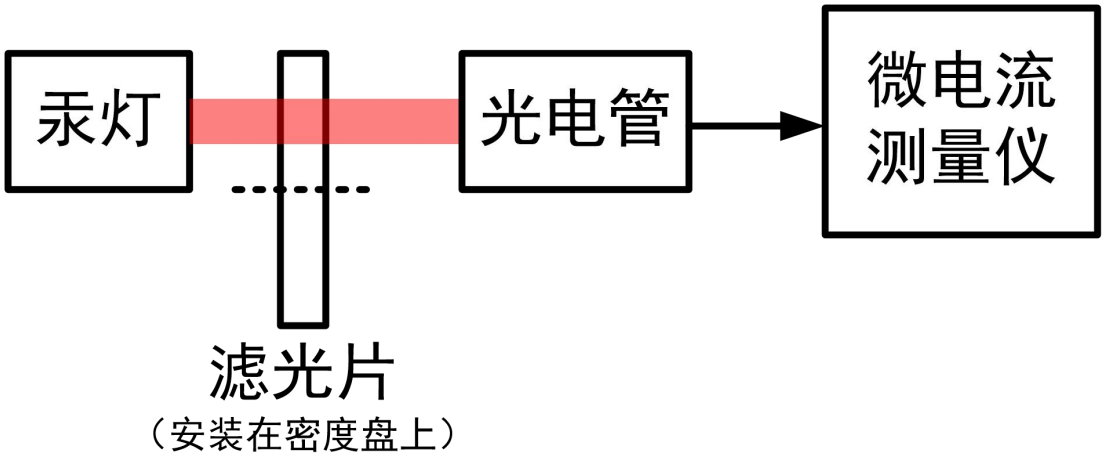
- Mercury lamp
- Filters (5 wavelengths available)
- GDH-1 type photoelectric tube
- Micro - current amplification measuring instrument



5. Operating procedures and methods

- Once the mercury lamp is turned on, do not turn it off.
- No require a darkroom environment, but avoid changes in background light.
- During the experiment, please pay attention to cover the cover of the mercury lamp at any time. Do not let the mercury light enter the photoelectric tube window directly without passing through the filter.
- The end of the experiment photoelectric tube and mercury lamp shade covered!
- The instrument should not be in a strong magnetic field, strong electric field, strong vibration, high temperature, with radiation material environment.
- Store the instrument in a ventilated and dry place, plus dust cover.

5.2 experiment layout



Prepare work

（1）Place the instrument and cover the light window and the light source window of the photoelectric cartridge respectively with the light window cover. Turn on the power switch and warm up for 10-30 minutes.

(2) the micro-current tester and the photocell tube between the wires connected to adjust the light source light window and the photoelectric tube box light window height, photoelectric tube box placed in the middle 40cm is appropriate.

5.3 Experimental regulation essentials

Measure the photocurrent characteristic curve of the I-V

（1） Basic parameter setting

Filter: 577nm; Voltage range: -2V ~ 50V; Current range: 10^{-11}A

（2）Light intensity setting

Light: mercury lamp to the photoelectric tube box distance of 30cm

Low light: mercury lamp to the photoelectric tube cartridge distance 40cm

5.3 Experimental regulation essentials

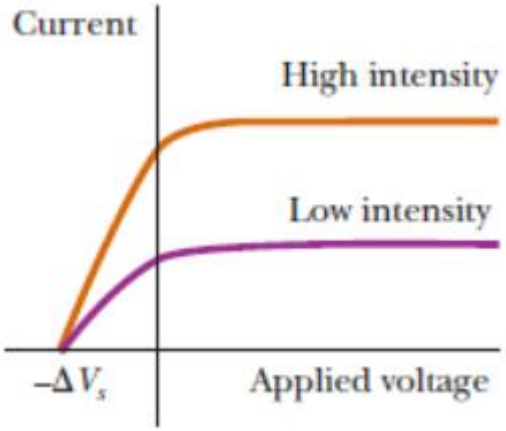
Measure the cut off voltage

（1） Basic parameter setting

Filter: 365nm, 405nm, 436nm, 546nm and 577nm choose one;

Voltage range: -2V ~ 0V; current range： 10^{-13}A

（2）judgment of cut off voltage



Measured voltammetry characteristics of photovoltaic cells as shown.

6. Exercise

- In this experiment, such as changing the illumination on the photoelectric tube, the I-V curve have any effect?

- Photocathode cathodes are coated with a small work out of the photosensitive material, and the anode is elected off the power of metal manufacturing, and why?

- Is it possible for photo-electricity to occur only on metal surfaces? why?

8. Data and process

8.1 cut off voltage

table1 cut-off voltage with different frequency

Wavelength (nm)	Frequency (Hz)	Stopping potential (V)
365		
405		
436		
546		
577		

8. 2 I-V curve of photo-electric tube

Table 3 I-V curve

ΔV/V	-2.0	0.0	2.0	4.0	6.0	8.0	10.0	12.0
d=30cm, $I/10^{-11}$A								
d=40cm, $I/10^{-11}$A								
ΔV/V	14.0	16.0	18.0	20.0	22.0	24.0	28.0	30.0
d=30cm, $I/10^{-11}$A								
d=40cm, $I/10^{-11}$A								
ΔV/V	32.0	34.0	36.0	38.0	40.0	43.0	46.0	50.0
d=30cm, $I/10^{-11}$A								
d=40cm, $I/10^{-11}$A								

for .

（1）least-square fitting find out the values of the Plancks constant and the work function of the metal in photoelectric tube.

（2）Use the data in Data Table 7-2 to draw a graph of the current depending on the voltage for the photoelectric tube illuminated by different intensities.