Department of theoretical physics and astrophysics of science faculty of Masaryk university in Brno

Physics laboratory III

2, Study of thermoelectron emission on anode

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Field of study: Astrophysics **Year of study:** 2011/2012 **Semester:** IV

Tasks:

1, Measure work *w* of wolfram by Richardson-Dushman line.

2, Calculate intensity of electric field near the surface of cathode.

3, Measure dependency of I_{nas} = f(Ua) for Ua < 150 V, process it in coordinates ln(I_{nas}) = √Ua and determine increment of current due the presence of electric field for Ua = 150 V. Compare experimentally obtained value with value determined by equation: $\Delta I_{nas} = I_{nas}(e^{\frac{w_p}{kT}} - 1) = BT^2 e^{\frac{w_p}{kT}}(e^{\frac{w_p}{kT}} - 1)$

4, Measure zone of starting current and make a graph for two values of incandescent current If. Do the same for coordinates ln I = f(Ua) and determine temperature of electrons.

1, Richardson-Dushman equation:

$$I_{nas} = BT^2 e^{\frac{-w}{kT}}$$

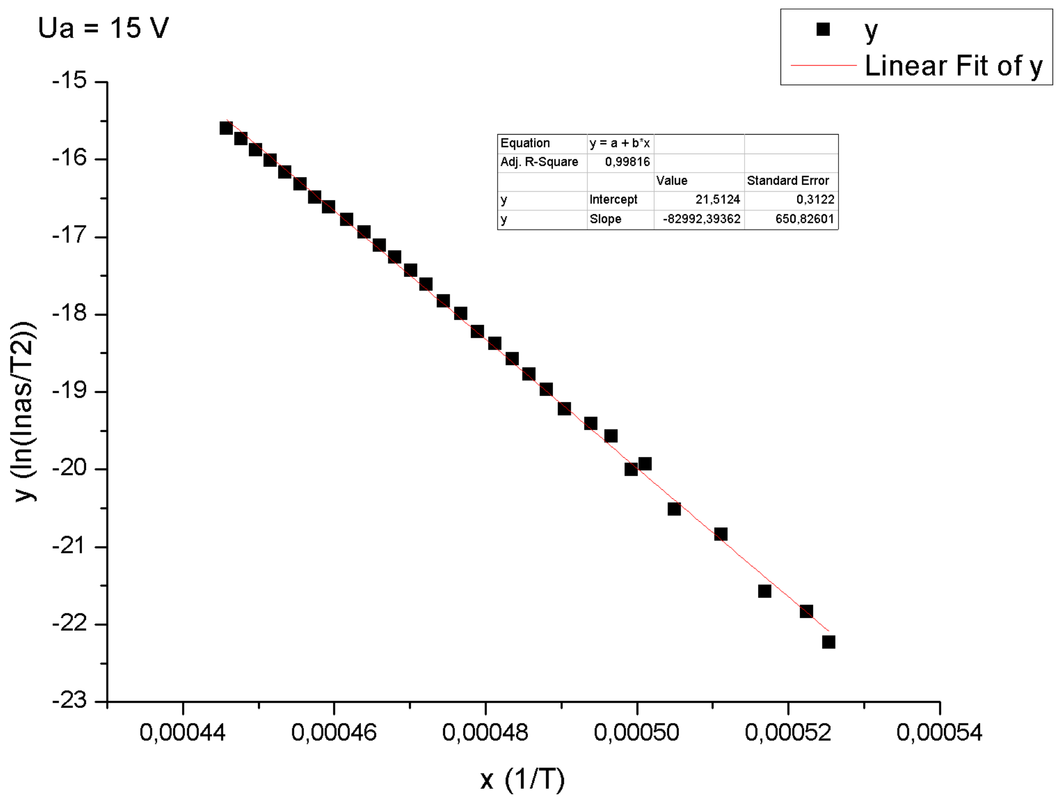
$$\ln\left(\frac{I_{nas}}{T^2}\right) = \frac{-w}{k}\frac{1}{T} + \ln(B)$$

Work is slope of this function for values of I_{nas}, T, k and B are constant. We need to calculate temperature T from this formula:

$$R_t = \frac{\rho \cdot d}{S}(1 + \alpha T)$$

where $\rho = 4{,}89\text{x}10^{-8}$ Ωm, $\alpha = 4{,}83\text{x}10^{-3}K^{-1}$, $d = 15\text{x}10^{-3}$ m and $S = \pi r^2 = 7{,}854\text{x}10^{-9}$ m^2. Temperature of wolfram cathode for Ua = 15 V and lowest current is 1903 K. The rest of value can be seen in table below:

Uf	If	Ua	Ia	T	x	y
[V]	[A]	[V]	[μA]	[K]	1/T	$\ln(I_{nas}/T^2)$
0,85925	1,03676	15,00391	8E-4	1903,43085	5,25367E-4	-22,23373
0,86848	1,04191	15,00411	0,0012	1913,99626	5,22467E-4	-21,83933
0,88653	1,05186	15,00418	0,0016	1934,54778	5,16917E-4	-21,57301
0,90543	1,06184	15,00407	0,0034	1956,43866	5,11133E-4	-20,84174
0,92537	1,07186	15,00407	0,0048	1980,021	5,05045E-4	-20,52086
0,93729	1,07699	15,004	0,0088	1995,42773	5,01146E-4	-19,93023
0,94509	1,08183	15,00402	0,0082	2002,80074	4,99301E-4	-20,00822
0,95471	1,08687	15,00376	0,0128	2013,446	4,96661E-4	-19,57352
0,96462	1,09199	15,00381	0,0152	2024,4201	4,93969E-4	-19,41254
0,97618	1,09692	15,00418	0,0186	2038,98054	4,90441E-4	-19,225
0,98565	1,10196	15,00405	0,0242	2049,01565	4,88039E-4	-18,97163
0,99474	1,10681	15,00391	0,0298	2058,52287	4,85785E-4	-18,77273
1,00414	1,11196	15,00391	0,0366	2068,02466	4,83553E-4	-18,57641
1,01343	1,11688	15,00395	0,045	2077,66273	4,8131E-4	-18,37909
1,02314	1,122	15,00381	0,0528	2087,67098	4,79003E-4	-18,22885
1,03278	1,12706	15,00397	0,0672	2097,54284	4,76748E-4	-17,99713
1,04225	1,1319	15,00355	0,0798	2107,41797	4,74514E-4	-17,83467
1,05214	1,13698	15,00351	0,1004	2117,57681	4,72238E-4	-17,61465
1,06156	1,1419	15,00383	0,121	2127,01462	4,70143E-4	-17,43691
1,07113	1,14703	15,00381	0,1444	2136,3029	4,68098E-4	-17,26883
1,08059	1,15185	15,00416	0,1708	2145,84512	4,66017E-4	-17,10984
1,0903	1,15699	15,00397	0,2044	2155,20539	4,63993E-4	-16,93896
1,10057	1,16209	15,00407	0,243	2165,64372	4,61756E-4	-16,77564
1,11122	1,16696	15,00367	0,2864	2177,11381	4,59324E-4	-16,62188
1,12075	1,17211	15,0037	0,328	2185,85016	4,57488E-4	-16,49426
1,1305	1,17707	15,00392	0,393	2195,28301	4,55522E-4	-16,32208
1,14047	1,18205	15,00397	0,4606	2205,01081	4,53513E-4	-16,1722
1,15035	1,18711	15,00391	0,5414	2214,36106	4,51598E-4	-16,01904
1,16018	1,19198	15,00365	0,628	2223,86087	4,49668E-4	-15,87922
1,17048	1,19717	15,00395	0,7302	2233,56335	4,47715E-4	-15,73714
1,18028	1,202	15,0036	0,8434	2242,93732	4,45844E-4	-15,6014



The slope of Richardson-Dushman line is -82992,39362 which is equal to -*w*/k where k is Boltzmann constant. Work *w* is then $1{,}1458 \times 10^{-18}$ J = 7,15 eV.

2 & 3, Intensity of electric field is defined as:

$$E = U_a \frac{1}{r \cdot \ln(R/r)}$$

where R = 0,7 mm and r= 0,005 mm. For maximal Ua = 150 V we get E = $6{,}071 \times 10^{6}$ Vm^{-1}. The decrease of work is then:

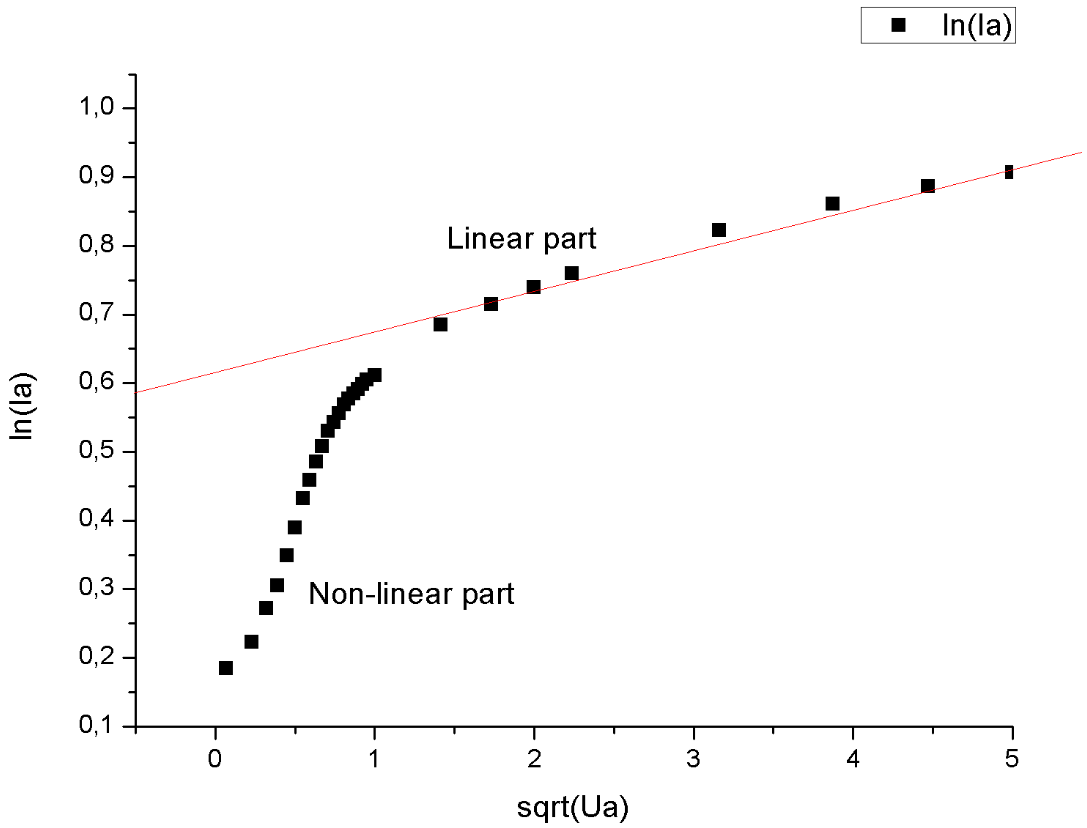
$$w_p = \sqrt{\frac{e^3 E}{4 \pi \epsilon_0}}$$

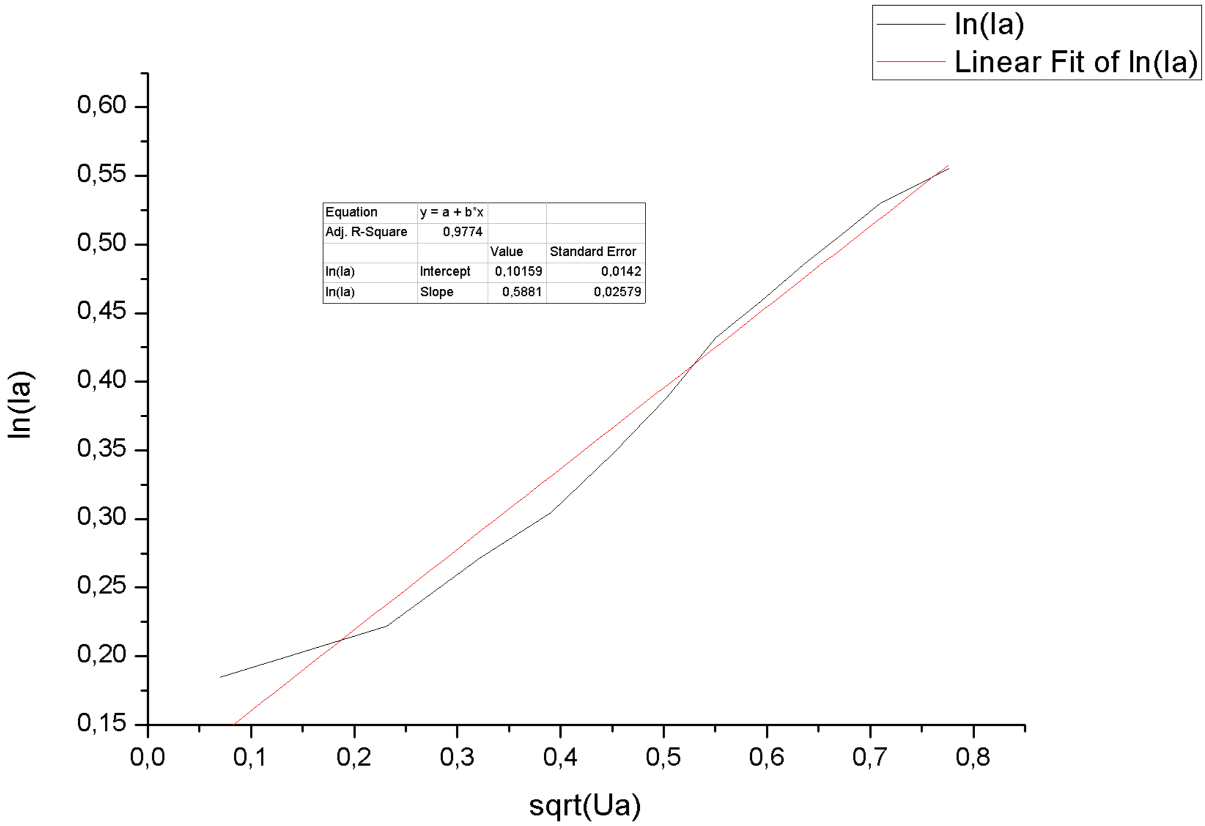
$w_p = 1{,}498 \times 10^{-20}$ J = 0,093 eV.

$$\Delta I_{nas} = I_{nas}\left(e^{\frac{w_p}{kT}} - 1\right) = BT^2 e^{\frac{w_p}{kT}}\left(e^{\frac{w_p}{kT}} - 1\right)$$

Due to measuring components we were able to measure Ua only from -50 V to 50 V.

ΔI_{nas} = 0,22 μA





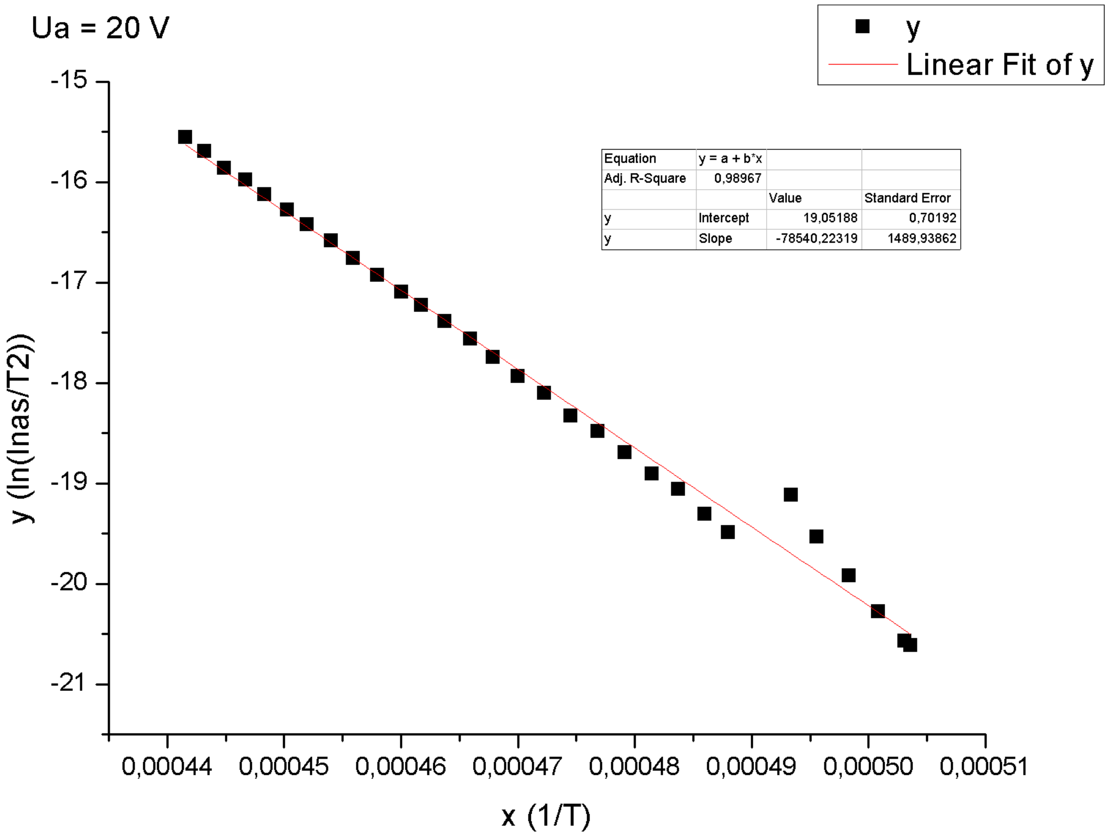
From this graph I acquired work by this formula:

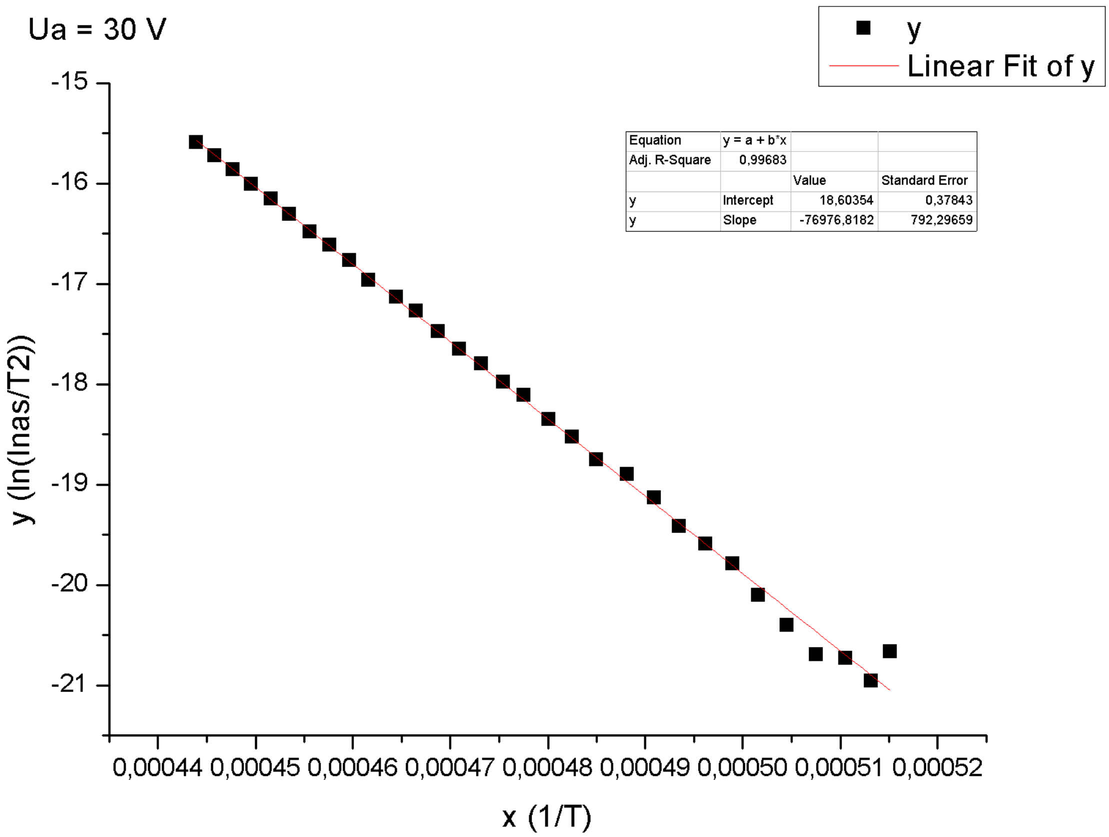
$$w_p = (A\sqrt{U_a} - B)\,kT = 0{,}0214\,eV$$

Conclusion:

In this laboratory we measured work *w* = 7,15 eV, intensity of electrical field E = $6{,}071 \times 10^6\ Vm^{-1}$. We determined current addiction ΔI_{nas} = 0,22 μA. And at last we found out work decrease w_p = 0,0214 eV.

Appendix:


Ua = 20 V
y
Linear Fit of y
Equation | y = a + b*x
Adj. R-Square | 0,98967
Value | Standard Error
y | Intercept | 19,05188 | 0,70192
y | Slope | -78540,22319 | 1489,93862
-15
-16
-17
-18
-19
-20
-21
y (ln(Inas/T2))
0,00044 0,00045 0,00046 0,00047 0,00048 0,00049 0,00050 0,00051
x (1/T)


Ua = 30 V
y
Linear Fit of y
Equation | y = a + b*x
Adj. R-Square | 0,99683
Value | Standard Error
y | Intercept | 18,60354 | 0,37843
y | Slope | -76976,8182 | 792,29659
-15
-16
-17
-18
-19
-20
-21
y (ln(Inas/T2))
0,00044 0,00045 0,00046 0,00047 0,00048 0,00049 0,00050 0,00051 0,00052
x (1/T)