№	Para-graph	Question (criteria)	Total per question	Points
1		**Measurement of the dependence of the resistance of a part of the wire on its length (12)**		
	1.1.	**Table with results ($\boldsymbol{R, l}$) from the video**	**2**	
		R, l in the table		1
		If ≥ 10 points		1
	1.2.	**Measurement scheme**	**1**	
		Ohmmeter, nichrome wire		1
	1.3.	**Theoretical formula**	**1**	
		$R = \frac{\rho l}{S}$		1
	1.4.	**Graph $\boldsymbol{R(l)}$**	**6**	
		Axes are labeled		0.5
		Correct scale		0.5
		If ≥ 10 points		1
		Straight line		1
		$a \in [1.20\ ; 1.40]\ \frac{Ohm}{cm}$		0.5
		$a \in [1.28\ ; 1.38]\ \frac{Ohm}{cm}$		0.5
		$b \in [1.4\ ; 2.2]\ Ohm$		1
		Brief interpretation of the approximation parameters a and b		1
2		**Preparing a computer program for work (8)**		
	2.1.	**Diagram of the set-up**	**1**	
		Camera, ruler		1
	2.2.	**Table with the coordinates on the ruler (x) in centimeters and the pixel number (n)**	**1**	
		≥ 8 points		1
	2.3.	**Graph x(n)**	**3**	
		Axes are labeled		0.5
		Correct scale		0.5

		≥ 8 points		1
		Straight line (x = Kn + b)		1
	2.4.	**Value of the angular slope coefficient K**	**2**	
		$K \in \pm[0.010\ ;0.012]\,\frac{cm}{pix}$		2
3		**Measurement of the diameter of a nichrome wire in an unstressed state using a diffraction pattern (14.5)**		
	3.1.	**Scheme of the setup for obtaining and studying the diffraction pattern**	**2**	
		Screen, nichrome wire, laser		1
		Mark with letters the required distances measured in the experiment (l, x)		1
	3.2.	**Distance between the screen and the wire**	**1**	
		$l\ \in [52.4\ ; 52.6]$ cm		1
	3.3.	**Table with the coordinate of the diffraction minimum (x) on its number (N)**	**2**	
		≥ 7 points on positive N		1
		≥ 7 points on negative N		1
	3.4.	**Formula describing the relationship between the coordinates of the minima (x) and their numbers (N)**	**1**	
		$x\ = x_0 + \frac{n\lambda l}{d}$		1
	3.5.	**Plot the dependence x(N)**	**7**	
		Axes are labeled		0.5
		Correct scale		0.5
		If ≥ 7 points on each side from central maximum (total points ≥ 14)		1
		The graph contains points with N > 15 and < -15		1
		Straight line		1
		Determine to what minimum number the graph can be considered linear: It is written about the deviation from a straight line in the section with N < -15 **or** about the incorrectness of determining the minimum point at large values of N due to the blurring of the light intensity graph from the coordinate.		1

		Slope of a linear part of the graph: $k \in [0.34\,;0.36]$ cm		2
	3.6.	**Calculate the diameter (d_0)**	**2**	
		$d_0 \in [93\,;101]\,\mu m$		1
		$d_0 \in [95\,;99]\,\mu m$		1
4		**Investigation of the parameters of nichrome wire when it is stretched. (23)**		
	4.1.	**Table with the coordinates of the contacts for the investigated section of the wire (L_1 and L_2), and the readings of the voltmeter (U) and ammeter (I)**	**2**	
		If ≥ 10 points		1
		Include steps from < 3 and >16		1
	4.2.	**The numbers of the selected minima, the distance between which will be measured.**	**2**	
		One minimum is negative and another minimum is positive ($n_1 \cdot n_2 < 0$)		1
		the quantity Δx is written in table 4.1		1
	4.3.	**Write down the formulas**	**2**	
		a) the formula for determining the length of the investigated section of the wire (L)		0.5
		b) the formula for calculating the electrical resistance of the investigated section of the wire (R)		0.5
		c) expression for calculating the diameter of the wire (d)		1
	4.4.	**The table the length of the selected wire section (L), its electrical resistance (R) and wire diameter (d) values for each stretching step.**	**1**	
		≥ 10 points		0.5
		= 18 points		0.5
	4.5.	**The relationship between the logarithm of the diameter and the logarithm of the length of the wire section.**	**3**	
		$\ln d = \ln d_0 + \mu \ln L_0 - \mu \ln L$ or something like this		2
		ln(L/cm) and ln(d/μm) in the table in paragraph 4.4. for each line		1
	4.6.	**Plot the dependence ($\boldsymbol{ln\ d(ln\ L)}$)**	**5**	
		Correct scale		0.5

		Axes are labeled		0.5
		If ≥ 10 points		0.5
		= 18 points		0.5
		Straight line		1
		The resulting Poisson's ratio (μ) from graph $ln\ d(ln\ L)$): μ ∈ [0.38 ; 0.46]		1
		μ ∈ [0.40 ; 0.44]		1
	4.7.	**The derivation of the formula $\boldsymbol{ln\ R(ln\ L)}$, assuming the resistivity of the wire to be constant.**	**3**	
		$$\ln R = \ln\frac{4\rho}{\pi d_0^2 l_0^{2\mu}} + (1+2\mu)\ln l$$		2,5
		The values of $ln\ R$ in the table in paragraph 4.3.		0.5
	4.8.	**Plot the dependence $\boldsymbol{lnR(lnL)}$.**	**4**	
		Axes are labeled		0.5
		Correct scale		0.5
		≥ 10 points		0.5
		= 18 points		0.5
		The slope (k) of the resulting graph: $k \in [1.8 ; 2.0]$		2
	4.9.	**Draw a conclusion about how the resistivity changes with increasing wire length.**	**2.5**	
		«does not change»		0.5
		It is written similar to the following: "μ is approximately equal to $\mu \approx \frac{k-1}{2}$, so our assumption about ρ was correct"		1
		Comparison of the values of μ obtained in this and the previous paragraph is done with an analysis of the error for μ and k		1
5		**Determination of the thermal resistance coefficient (18)**		
	5.1.	**The value of the voltage on the wire ($\boldsymbol{U_t}$) at room temperature**	**1**	
		$U_t \in [1252 ; 1260]$ mV		1

	5.2.	**Table with the voltage values between points A and B (U_{AB}) and corresponding temperature values (t)**	**1**	
		≥ 10 points when cooling down		1
	5.3.	**Electrical diagram for this part**	**1**	
		Drawn (bridge circuit, voltmeter)		0.5
		Mark with letters the parameters necessary for further calculations		0.5
	5.4.a)	**Write the derivation of the formula expressing the change in the resistance of the wire $\Delta R(R_0, U, U_t)$.**	**5**	
		U_{AB} is expressed in terms of the resistance of the resistors and the voltage at the source $$U_{AB} = \frac{U}{R_3 + R}R - \frac{U}{R_1 + R_2}R_2$$ Or in some way the following was obtained...		1
		An expression of the following form is obtained: $$\Delta R = \frac{R_0 U_{AB} U}{U_t(U - U_t)}$$ **Or** taking into account that at room temperature the resistances in each branch of the electrical circuit are approximately equal, the following expression is obtained: $$\Delta R = \frac{4 \cdot R_0 U_{AB}}{U}$$		2
		$$\Delta R = \frac{R_0 U_{AB} U}{U_t(U - U_t)}$$		2
	5.4.b)	**The derivation of the formula expressing the voltage between points A and B $U_{AB}(t, U, U_t, \alpha)$.**	**2**	
		The following expression is obtained: $$U_{AB} = \frac{U_t(U - U_t)}{U} \cdot \alpha \Delta t = \frac{U_t(U - U_t)}{U} \cdot \alpha(t - t_0)$$ **Or** $U_{AB} = \frac{U}{4} \cdot \alpha(t - t_0)$		1
		$$U_{AB} = \frac{U_t(U - U_t)}{U} \cdot \alpha(t - t_0)$$		1
	5.4.	**Write down the final formulas**	**1**	
		Final formulas		1

	5.5.	**Plot the dependence $U_{AB}(t)$**	**7**	
		Axes are labeled		0.5
		Correct scale		0.5
		≥ 10 points when cooling down		1
		Part of the graph can be considered linear when cup is cooling down + straight line		1
		$\alpha \in [0.35\,;0.43] \cdot 10^{-3} \frac{1}{°C}$		1
		$\alpha \in [0.37\,;0.41] \cdot 10^{-3} \frac{1}{°C}$		1
		$\alpha \in [0.38\,;0.40] \cdot 10^{-3} \frac{1}{°C}$		1
		Lower temperature limit 46 ± 3 °C		0.5
		Upper temperature limit 70 ± 3 °C		0.5
6		**Investigation of elastic deformations of the wire (24.5)**		
	6.1.	**Table with the coordinates of the spring markers (x_1 and x_2) and the mass of the load (m) on the spring.**	**1.5**	
		= 8 points		1
		The spring length (x) and the spring load force (F) in the table for each line		0.5
	6.2.	**Plot the dependence of the spring load force on the spring length $F\,(x)$.**	**6**	
		Axes are labeled		0.5
		Correct scale		0.5
		Straight line		1
		= 8 points		1
		$a \in [0.22\,;0.24] \frac{N}{cm}$		1
		$b \in [-1.11\,;-1.01]\,N$		1
		Brief interpretation: $a = k$ - coefficient of elasticity of the spring.		0.5
		b - coefficient that arises due to the fact that the spring has an initial length		0.5
	6.3.	**The table of the coordinates (x_1 and x_2) and the readings U'_{AB}.**	**4**	

		≥ 18 points		1
		The length of the spring (x) in the table		1
		$S \in [6.7\,;8.1] \cdot 10^{-9}$ m^2		1
		$U_0 \in [1275\,;1279]$ mV		1
	6.4	**Derive the formula expressing the dependence of the amplified voltage between points A and B (U_{AB}')**	**4**	
		Using the expression from Part 4: $\frac{dR}{R_0} = k' \cdot \frac{dL}{L}$		1
		Using the Young's Modulus expression to get the final formula: $\frac{dL}{L} = \frac{\Delta F/S}{E}$		1
		Final formula: $U_{AB}' = G \cdot k' \cdot \frac{kx/S}{E} \cdot \frac{U_0(U-U_0)}{U}$ **Or** $U_{AB}' = G \cdot k' \cdot \frac{kx/S}{E} \cdot \frac{U}{4}$		1
		Final formula $U_{AB}' = G \cdot k' \cdot \frac{kx/S}{E} \cdot \frac{U_0(U-U_0)}{U}$		1
	6.5.	**Plot the dependence ($x(U_{AB}')$)**	**5**	
		Axes are labeled		0.5
		Correct scale		0.5
		≥ 18 points		1
		Straight line		1
		$c \in [0.73\,;0.89]\ \frac{m}{V}$		1
		$c \in [0.76\,;0.86]\ \frac{m}{V}$		1
	6.6.	**Express the Young's modulus (E) through the slope (c) of the plotted graph.**	**3**	
		$E = \frac{G \cdot k' \cdot k \cdot c}{S} \cdot \frac{U_0(U-U_0)}{U}$ **Or** $E = \frac{G \cdot k' \cdot k \cdot c}{S} \cdot \frac{U}{4}$		0.5
		$E = \frac{G \cdot k' \cdot k \cdot c}{S} \cdot \frac{U_0(U-U_0)}{U}$		0.5
		$E \in [1.1\,;1.3] \cdot 10^{11}\ \frac{N}{m^2}$		2

	6.7.	**Using the graph, determine the maximum wire tension**	**2**	
		$F_{max} \in [3.3\ ;\ 4.3]$ N		1
		$F_{max} \in [3.5\ ;\ 4.1]$ N		1