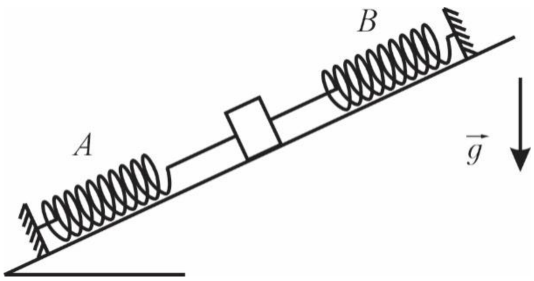
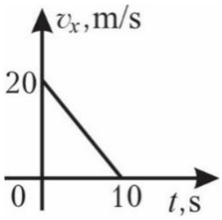
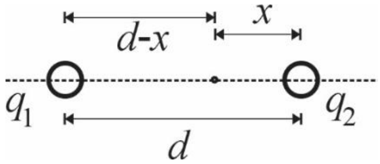
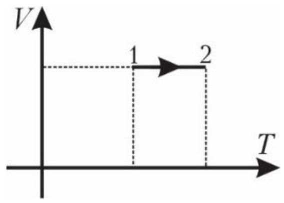
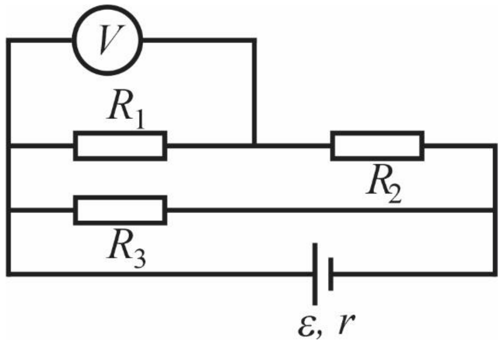
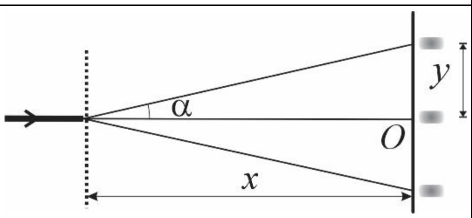
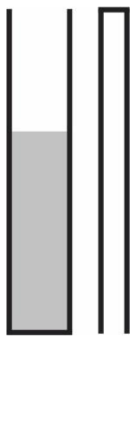
No.	Item	Score	
I. FOR ITEMS 1-3 PROVIDE SHORT ANSWERS ACCORDING TO THE GIVEN REQUIREMENTS			
1	**Complete the following sentences as to make true statements:** **a)** If the work done by the net force acting on a body is positive, the kinetic energy of the body…………………………………….. . **b)** In the uniform circular motion of a material point, the acceleration is …………………………… to the velocity vector. **c)** During the isothermal expansion of a gas, the gas ……………………….. heat. **d)** When the direction of the electric current through a straight conductor is reversed, the direction of the magnetic field lines produced by it is……………………………….. . **e)** Radioactive decay with the emission of an alpha particle changes the charge number of the decaying nucleus by ……………………….. units.	L 0 2 4 6 8 10	L 0 2 4 6 8 10
2	**Indicate (by using arrows) the correspondence between the following physical quantities and the physical units they represent:** Centripetal acceleration — J Mechanical work — J/(mol·K) Molar heat capacity — mT Electromotive force — m/s^2 Magnetic field induction — V/m kV	L 0 2 4 6 8 10	L 0 2 4 6 8 10
3	**State whether the following statements are true or false and circle the right answer:** a) The work of the gravitational force is negative during the upward motion of a body. **T F** b) A gas cools down if it is compressed adiabatically. **T F** c) If the electric current flowing through a coil varies, a self-induction voltage appears at its terminals. **T F** d) A negative electric charge placed in an electric field will move under the action of the field in the same direction as the field lines. **T F** e) The rest energy of a relativistic particle is the same in all inertial reference frames. **T F**	L 0 2 4 6 8 10	L 0 2 4 6 8 10
II. IN EXERCISES 4-9 ANSWER THE QUESTIONS OR SOLVE THE TASKS, AND PROVIDE ARGUMENTS IN THE SPACES BELOW:			
4	A body placed on a smooth inclined plane is kept at rest by means of two compressed elastic springs, *A* and *B*. Qualitatively represent in the figure all the forces acting on the body. 	L 0 1 2 3 4	L 0 1 2 3 4
5	Determine the stopping potential of the photoelectrons if the work function of the cathode is $L_e = 6.0 \cdot 10^{-19}$ J, and the wavelength of the photons incident on the cathode is $\lambda = 198.9$ nm. SOLUTION	L 0 1 2 3 4 5 6	L 0 1 2 3 4 5 6

6	The figure shows the graph of the time dependence of the velocity projection of a body moving with uniformly decelerated rectilinear motion. Determine the distance traveled by the body along the *Ox* axis during the first $t_1 = 4{,}0$ s of motion. SOLUTION  	L 0 1 2 3 4 5	L 0 1 2 3 4 5
7	Two charged point bodies with charges $q_1 < 0$ and $q_2 < 0$ are placed in vacuum at a distance $d = 20$ cm from each other. Determine the distance x from the second body, on the line joining the bodies, at which the resultant electric field intensity is zero, if the ratio of the electric charges is $q_1/q_2 = 16$. SOLUTION  	L 0 1 2 3 4 5 6 7	L 0 1 2 3 4 5 6 7

8	A quantity of monatomic ideal gas occupying the initial volume $V = 4{,}0$ L is heated so that its pressure increases by $\Delta p = 50$ kPa. Analyze the graph of the dependence of the gas volume on temperature, identify the thermodynamic process, and determine the amount of heat received by the gas in this process. SOLUTION 	L 0 1 2 3 4 5 6 7 8 9	L 0 1 2 3 4 5 6 7 8 9
9	In the circuit shown in the figure, the resistances of the resistors are $R_1 = 10\ \Omega$, $R_2 = 20\ \Omega$, and $R_3 = 30\ \Omega$. The source has an electromotive force $\varepsilon = 12$ V and an internal resistance $r = 5\ \Omega$. What voltage U_1 will the ideal voltmeter indicate? SOLUTION 	L 0 1 2 3 4 5 6 7 8 9	L 0 1 2 3 4 5 6 7 8 9

	III. FOR ITEMS 10-12 PROVIDE FULL SOLUTION TO THE GIVEN PROBLEMS		
10	A metal ball is launched vertically upward with the initial speed $v_1 = 20\ \text{m/s}$ from the height h_1 above the ground. It then collides with a rigid horizontal surface placed on the ground. The temperatures of the ball before and after the collision are $T_1 = 19\ ℃$ and $T_2 = 20\ ℃$. After the collision, the ball rises to the maximum height $h_2 = 25$ m. Determine the height h_1 from which the ball was launched. The energy transferred to the rigid surface is neglected. The specific heat capacity of the metal of the ball is $c = 400\ \text{J/(kg}\cdot\text{K)}$. Free fall acceleration is $g = 10\ \text{m/s}^2$. SOLUTION	L 0 1 2 3 4 5 6 7 8 9 10 11	L 0 1 2 3 4 5 6 7 8 9 10 11
11	A laser beam with wavelength $\lambda_1 = 0{,}70\ \mu\text{m}$ is normally incident on a diffraction grating, so that diffraction maxima are obtained on a screen placed at a distance $x = 2{,}4$ m. The radiation wavelength is changed to λ_2, $\lambda_2 < \lambda_1$, and the grating is moved uniformly along the incident beam, without being rotated, at a speed $v = 20\ \text{mm/s}$. After $t = 30$ s from the beginning of the motion, the first-order maximum returns to its initial position. Determine the wavelength λ_2. State whether the grating moved away from the screen or toward it. 		

	SOLUTION Underline the correct answer: the grating moved **closer** to / **away** from the screen.	L 0 1 2 3 4 5 6 7 8 9 10 11	L 0 1 2 3 4 5 6 7 8 9 10 11
12	You have a ruler and two glass cylindrical tubes of different diameters, closed at one end, such that the narrower tube can be inserted into the wider one. The wider tube contains an unknown liquid. Atmospheric pressure and free fall acceleration are assumed to be known. The temperature of the liquid and of the air is the same. Determine the density of the liquid. Capillary effects are neglected. a) Describe the procedure and draw a diagram indicating the measured quantities. b) Derive the formula used to calculate the density of the liquid. SOLUTION 	a) L 0 1 2 3 4 b) L 0 1 2 3 4	a) L 0 1 2 3 4 b) L 0 1 2 3 4

ANNEX

Physical constants

Elementary charge	$e = 1{,}60 \cdot 10^{-19}\mathrm{C}$	Avogadro's constant	$N_A = 6{,}02 \cdot 10^{23}\mathrm{mol}^{-1}$
Electron rest mass	$m_e = 9{,}11 \cdot 10^{-31}\mathrm{kg}$	Boltzmann's constant	$k = 1{,}38 \cdot 10^{-23}\ \mathrm{J/K}$
Light speed in vacuum	$c = 3{,}00 \cdot 10^{8}\mathrm{m/s}$	Ideal gas constant	$R = 8{,}31\ \mathrm{J/(mol \cdot K)}$
Gravitational constant	$K = 6{,}67 \cdot 10^{-11}\mathrm{N \cdot m^2/kg^2}$	Planck's constant	$h = 6{,}63 \cdot 10^{-34}\ \mathrm{J \cdot s}$
Electric constant	$\varepsilon_0 = 8{,}85 \cdot 10^{-12}\mathrm{F/m}$	Coulomb's force constant	$k_e = 9{,}0 \cdot 10^{9}\mathrm{N \cdot m^2/C^2}$

MECHANICS

$$x = x_0 + v_x t;\ \ x = x_0 + v_{0x}t + \frac{a_x t^2}{2};\ v_x = v_{0x} + a_x t;\ v_x^2 - v_{0x}^2 = 2a_x s_x;\ \nu = \frac{1}{T};\ \omega = \frac{2\pi}{T};\ v = \omega r;\ a_c = \frac{v^2}{r}.$$

$$\vec{F} = m\vec{a};\ \vec{F}_{12} = -\vec{F}_{21};\ F = K\frac{m_1 m_2}{r^2};\ \Gamma = K\frac{m}{r^2};\ G = mg;\ \vec{F}_e = -k\Delta\vec{l};\ F_f = \mu N;\ F_A = \rho_0 V g;\ p = \frac{F}{S};\ p = \rho g h;$$

$$M = Fd;\ \vec{p} = m\vec{v};\ \Delta\vec{p} = \vec{F}\Delta t;\ L = Fs\cos\alpha;\ P = \frac{L}{t};$$

$$E_c = \frac{mv^2}{2};\ L_{12} = E_{c2} - E_{c1};\ E_p = mgh;\ E_p = \frac{kx^2}{2};\ L_{12} = -(E_{p2} - E_{p1});$$

$$\nu = \frac{N}{t};\ T = \frac{t}{N};\ T = 2\pi\sqrt{\frac{l}{g}};\ T = 2\pi\sqrt{\frac{m}{k}};\ v = \lambda\nu;\ \lambda = vT;\ x = A\sin(\omega t + \varphi_0);\ v_m = A\omega;\ a_m = A\omega^2$$

MOLECULAR PHYSICS AND THERMODYNAMICS

$$p = \frac{1}{3}m_0 n\overline{v^2} = \frac{2}{3}n\bar{\varepsilon}_{tr};\ \bar{\varepsilon}_{tr} = \frac{3}{2}kT;\ p = nkT;\ v_T = \sqrt{\frac{3RT}{M}};\ pV = \nu RT;\ \nu = \frac{m}{M} = \frac{N}{N_A};\ R = kN_A;\ M = m_0 N_A;$$

$$pV = const, T = const;\ \frac{p}{T} = const, V = const;\ \frac{V}{T} = const, p = const;\ \frac{pV}{T} = const, m = const.$$

$$Q = \Delta U + L;\ U = \frac{3}{2}\frac{m}{M}RT;\ L = p\Delta V;\ Q = cm\Delta T = C_M \nu\Delta T;\ Q = \lambda m;\ Q = qm;\ c_p - c_V = \frac{R}{M};$$

$$\eta = \frac{Q_1 - |Q_2|}{Q_1};\ \eta_{max} = \frac{T_1 - T_2}{T_1};\ \varphi = \frac{\rho_a}{\rho_s} = \frac{p_a}{p_s};\ \sigma = \frac{F_s}{l};\ h = \frac{4\sigma}{\rho g d};\ \frac{F}{S} = E\frac{\Delta l}{l_0};\ l = l_0(1 + \alpha t);\ V = V_0(1 + \beta t)$$

ELECTRODYNAMICS

$$q = \pm Ne;\ F = \frac{k_e}{\varepsilon_r}\frac{|q_1 q_2|}{r^2};\ E = \frac{k_e}{\varepsilon_r}\frac{q}{r^2};\ k_e = \frac{1}{4\pi\varepsilon_0};\ \vec{E} = \frac{\vec{F}}{q};\ E = \frac{U}{d};\ \varphi = \frac{kQ}{r};\ W = \varphi q;\ U = \varphi_1 - \varphi_2;\ U = \frac{L}{q};$$

$$C = \frac{q}{U};\ C = \frac{\varepsilon_0\varepsilon_r S}{d};\ C_p = \sum_{i=1}^{n} C_i;\ \frac{1}{C_s} = \sum_{i=1}^{n}\frac{1}{C_i};\ W_e = \frac{CU^2}{2}$$

$$I = \frac{\Delta q}{\Delta t};\ I = \frac{U}{R};\ I = \frac{\varepsilon}{R + r};\ I_{sc} = \frac{\varepsilon}{r};\ R = \rho\frac{l}{S};\ R_S = \sum_{i=1}^{n} R_i;\ \frac{1}{R_p} = \sum_{i=1}^{n}\frac{1}{R_i};\ L = UIt;\ Q = I^2 Rt;\ P = UI;\ \eta = \frac{L_u}{L_t};$$

$$F = IBl\sin\alpha;\ F_L = qvB\sin\alpha;$$

$$\Phi = BS\cos\alpha;\ \varepsilon_i = -\frac{\Delta\Phi}{\Delta t};\ \Phi = Li;\ \varepsilon_{ai} = -L\frac{\Delta i}{\Delta t};\ W_m = \frac{LI^2}{2};$$

$$I = \frac{I_m}{\sqrt{2}};\ U = \frac{U_m}{\sqrt{2}};\ X_L = \omega L;\ X_C = \frac{1}{\omega C};\ \frac{I_2}{I_1} \approx K = \frac{N_1}{N_2} = \frac{U_1}{U_2};\ P = UI\cos\varphi;\ T = 2\pi\sqrt{LC};\ q = q_m\cos(\omega t + \varphi_0)$$

$$\Delta_{\max} = \pm 2k\frac{\lambda}{2};\ \Delta_{\min} = \pm(2k + 1)\frac{\lambda}{2};\ d\sin\varphi = \pm k\lambda;\ d = \frac{l}{N} = \frac{1}{n}$$

MODERN PHYSICS

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}};\ \vec{p} = \frac{m_0\vec{v}}{\sqrt{1 - \frac{v^2}{c^2}}};\ E = mc^2;\ E_0 = m_0 c^2;\ E_c = E - E_0;$$

$$\varepsilon_f = \frac{hc}{\lambda};\ p_f = \frac{h}{\lambda};\ m_f = \frac{h}{\lambda c};\ h\nu = L_e + \frac{mv_{max}^2}{2};\ \nu = \frac{c}{\lambda};\ h\nu = E_n - E_m;$$

$$N = N_0 e^{-\lambda t};\ \lambda = \frac{ln2}{T_{1/2}};\ N = N_0 2^{-\frac{t}{T_{1/2}}};\ {}^{A}_{Z}X \to {}^{A-4}_{Z-2}Y + {}^{4}_{2}He;\ {}^{A}_{Z}X \to {}^{A}_{Z+1}Y + {}^{0}_{-1}e$$

$$1\ \mathrm{eV} = 1{,}6 \cdot 10^{-19}\ \mathrm{J};\quad 1\ \mathrm{u} = 1{,}66 \cdot 10^{-27}\ \mathrm{kg}$$