# 1 Round

## 1.1 Task

A material point moves with an initial speed of 2 $m/s$ and a constant acceleration of 1 $m/s^2$, directed at an angle of 135 degrees to the initial speed direction.

### 1.1.1

How long will it take the velocity vector to turn 90 degrees from its initial direction? Give your answer in seconds and round to the nearest tenth.

**Answer: 2.8**

Solution: $V_0 + a\,cos(\alpha t) = 0$

$t = \dfrac{-V_0}{a\,cos(\alpha)} = \dfrac{-2}{1 \cdot cos(135°)} \approx 2{,}8s$

### 1.1.2

Find the velocity modulus of the material point at the time when the velocity vector turns 90° relative to the initial direction. Give your answer in $m/s$ to the nearest integer.

**Answer: 2**

Solution: $|V| = a\,sin(\alpha t) = a\,sin\alpha\,(\dfrac{V_0}{a\,cos(\alpha)})$

$|V| = -V_0 \cdot tan(\alpha) = -2 \cdot tan(135°) = 2\ m/s$

### 1.1.3

Find the displacement modulus of a material point while the velocity vector is turning 90° degrees relative to the initial direction. Give your answer in meters and round to the nearest integer.

**Answer: 4**

Solution: $S_x = V_0 t + \dfrac{a\,cos(\alpha t^2)}{2} = \dfrac{-V_0{}^2}{2a\,cos(\alpha)}$

$S_y = \dfrac{a\,sin(\alpha)}{2} \cdot t^2 = \dfrac{a\,sin(\alpha)}{2} \cdot \dfrac{V_0{}^2}{a^2\,cos^2(\alpha)} = \dfrac{V_0{}^2\,tan(\alpha)}{2a\,cos(\alpha)}$

$S = \sqrt{S_x{}^2 + S_y{}^2} = \sqrt{\dfrac{\frac{1}{4}V_0^4}{a^2\,cos^2(\alpha)} + \dfrac{V_0^4 \cdot tan^2(\alpha)}{4a^2\,cos^2(\alpha)}} = \left|\dfrac{V_0{}^2}{2a\,cos(\alpha)}\right| \sqrt{1 + tan^2(\alpha)} = 4\ m$

## 1.2 Task

Two bars of masses $m_1$ и $3m_1$ $kg$, moving in a straight line along a horizontal rough surface towards each other with speeds $V_1$ and $2V_1$ just before the collision, respectively and collide elastically with each other.

### 1.2.1

Find the ratio of the relative speed of the bars to the speed of the first bar. Give your answer to the nearest integer.

**Answer: 3**

Solution: $\left(\dfrac{V_1 + 2V_1}{V_1}\right) = 3$

### 1.2.2

Find the ratio of the distance that the first bar will move away from the point of collision to the distance that the second block will move away from the point of collision after the collision. Give your answer to the nearest integer.

**Answer: 49** Solution: velocities of the bars after collision:

$$V_1 = \frac{V_1(m_1 - m_2) - 2m_2 V_2}{m_1 + m_2} = \frac{V_1(m_1 - 3m_1) - 2 \cdot 3m_1 2V_1}{m_1 + 3m_1} = -3.5\, V_1$$

$$V_2 = \frac{2V_1 m_1 - V_2(m_2 - m_1)}{m_1 + m_2} = \frac{2V_1 m_1 - 2V_1(3m_1 - m_1)}{m_1 + 3m_1} = -0.5\, V_1$$

$$\frac{L_1}{L_2} = \left(\frac{V_2}{V_1}\right)^{-2} = \left(\frac{3.5}{0.5}\right)^2 = 49$$

### 1.2.3

Find the distance between the bars after stopping, if $m_1 = 1\ kg$ and $V_1 = 1\ m/s$, and the coefficient of friction between the bars and the surface is 0.1. Give your answer in meters to the nearest integer. The collision is elastic. All movements are translational and along one straight line. Take the free fall acceleration equal to 10 $m/s^2$.

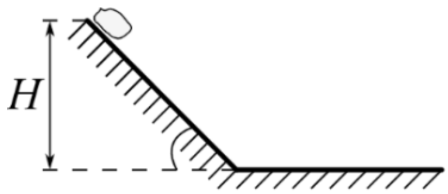
**Answer: 6**

Solution: $L_1 = \left(\frac{V_1^2}{2\,\mu g}\right)$; $L_2 = \left(\frac{V_2^2}{2\,\mu g}\right)$

$$L_1 - L_2 = \frac{V_1^2 - V_2^2}{2\,\mu g} = \frac{3.5^2 - 0.25}{2 \cdot 0.1 \cdot 10} = 6\ m$$

## 1.3 Task

A sand bag with a mass of 20 kg slides without initial speed from a height H = 2 m along a rough inclined surface, the angle of inclination to the horizon of which is 80°, turning into a horizontal rough surface. The coefficient of friction of the bag on the surfaces is 0.4. Take the free fall acceleration equal to 10 $m/s^2$.




### 1.3.1

Find the amount of heat released by the time the bag stops. Give your answer in $J$ to the nearest integer.

**Answer: 400**

Solution: $Q = mgH = 20 \cdot 10 \cdot 2 = 400\ J$

### 1.3.2

Find the speed of the bag just before the exit onto the horizontal surface. Give your answer in $m/s$ and round to the nearest tenth.

**Answer: 6.1**

Solution: $V = \sqrt{2\,gH(1 - \mu \cdot cot(\alpha))} = \sqrt{2 \cdot 10 \cdot 2(1 - 0.4 \cdot cot(80°))} \approx 6.1\ m/s$

### 1.3.3

Find the distance the bag will travel before stopping on a horizontal surface after the exit onto the horizontal surface. Give your answer in meters to the nearest integer. Consider the time of the collision of the bag and the horizontal surface to be negligible.

**Answer: 0**

Solution: because of $cos(\alpha) - \mu sin(\alpha) < 0$, that is why $L = 0$

## 1.4 Task

The equation of the process, in which one mole of a monatomic ideal gas is taken along is

$$\frac{P}{V} = const,$$

where P is pressure, V is volume.

### 1.4.1

Find how many times the gas temperature will increase when the gas pressure is increased by 3 times in this process. Give your answer to the nearest integer.

**Answer: 9**

Solution: $\frac{P}{V} = const \Rightarrow \frac{P^2}{T} = const$

$\frac{P_2^2 T_1}{P_1^2 T_2} = 1$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^2 = 9$

### 1.4.2

Find the heat capacity of the gas in this process. Give your answer in $\frac{J}{mol \cdot K}$ and round to the nearest tenth.

**Answer: 16.6**

Solution: $\frac{P}{V} = PV^{-1} = const$

$\frac{C - C_p}{C - C_V} = -1 \Rightarrow -C + C_V = C - C_p$

$2C = C_p + C_V \Rightarrow C = 2R = 2 \cdot 8.31 \approx 16.62 \ \frac{J}{mol \cdot K}$

### 1.4.3

Find the ratio of the work done by the gas when expanding from volume $V_1$ to volume $5V_1$ to the work done by the gas when expanding from volume $V_1$ to volume $2V_1$. Give your answer to the nearest integer. The amount of the gas in the process remains unchanged. Take the universal gas constant equal to 8.31 $\frac{J}{mol \cdot K}$.

**Answer: 8**

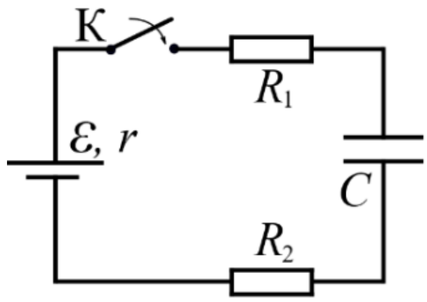
Solution: $P = \alpha V$

$A = \frac{\alpha}{2}(V_2^2 - V_1^2)$

$\frac{A_2}{A_1} = \frac{25-1}{4-1} = \frac{24}{3} = 8$

## 1.5 Task

The circuit shown in the figure has EMF $\varepsilon = 12\ V$, EMF internal resistance $r = 10\ ohms$, resistor $R_1 = 20\ ohms$, resistor $R_2 = 30\ ohms$, capacitor $C = 150\ \mu F$. The capacitor initially is not charged. Then the switch K is closed.




### 1.5.1

Find the current throuhg the circuit immediately after the switch is closed. Give your answer in $A$ to the nearest tenth.

**Answer: 0.2**

Solution: $I = \dfrac{\varepsilon}{R_1 + R_2 + r} = \dfrac{12}{20 + 30 + 10} = 0.2\ A$

### 1.5.2

Find the amount of heat released across the resistor $R_1$ after the key is closed. Give your answer in $mJ$ to the nearest tenth.

**Answer: 3.6**

Solution: $Q = \dfrac{C\varepsilon^2}{2} \cdot \dfrac{R_1}{R_1 + R_2 + r} = \dfrac{150 \cdot 10^{-6} \cdot 12^2}{2} \cdot \dfrac{20}{(20 + 30 + 10)} = 3.6\ mJ$

### 1.5.3

Find the modulus of the rate of change of current throuhg the circuit at a current half the maximum current. Give your answer in $A/s$ and round to the nearest tenth.

**Answer: 11.1**

Solution: $\dfrac{q}{C} + I(R_1 + R_2 + r) = \varepsilon \Rightarrow \dfrac{1}{C}\dfrac{da}{dt} + \dfrac{dI}{dt}(R_1 + R_2 + r) = 0$

$$\left|\frac{dI}{dt}\right| = \frac{I}{C(R_1 + R_2 + r)} = \frac{0.1}{150 \cdot 10^{-6} \cdot (20 + 30 + 10)} \approx 11.1\ A/s$$

# 2 Round

## 2.1 Task

A material point moves with an initial speed of 2 m/s and an acceleration that depends on time according to the law $a = \alpha \cdot t$, (where the constant $\alpha = 1\ m/s^3$) and directed perpendicular to the initial speed direction.

### 2.1.1

Find the velocity modulus of the material point at the time when the velocity vector turns 45° relative to the initial direction. Give your answer in $m/s$ and round to the nearest tenth.

**Answer: 2.8**

Solution: $|V| = \sqrt{2}V_0 \approx 2.8\ m/s$

### 2.1.2

Find the time it takes the velocity vector to turn 45° from its initial direction. Give your answer in seconds to the nearest integer.

**Answer: 2**

Solution: $V_0 = \dfrac{\alpha t^2}{2};\ t = \sqrt{\dfrac{2V_0}{\alpha}} = \sqrt{\dfrac{2 \cdot 2}{1}} = 2\ s$

### 2.1.3

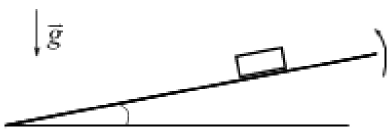
Find the radius of curvature of the trajectory of the material point at the time when the velocity vector turns 45° relative to the initial direction. Give your answer in meters and round to the nearest tenth.

**Answer: 5.7**

Solution: $R = \dfrac{V^2}{\alpha t\, cos(\varphi)} = \dfrac{(\sqrt{2}V_0)^2}{\alpha t\, cos(\varphi)} = \dfrac{2 \cdot 4 \cdot 2}{1 \cdot 2 \cdot \sqrt{2}} = \dfrac{8}{\sqrt{2}} = 5.7\ m$

## 2.2 Task

The bar lies on a frictionless, horizontal board. The angle of inclination of the board begins slowly and uniformly increase by turning the board relative to one of its ends with an angular velocity of 1 degree per second.




### 2.2.1

Find the acceleration of the bar one second after the board starts turning. Give your answer in $m/s^2$ and round to the nearest hundredth.

**Answer: 0.17**

Solution: $a = g \cdot sin(\omega t) \approx g \cdot \omega t \approx 10 \cdot rad(1°) \cdot 1 \approx 0.17\ m/s^2$

### 2.2.2

Find the ratio of the speed of the bar relative to the board three seconds after the start of movement to the speed of the bar relative to the board one second after the start of movement. Give your answer to the nearest integer.

**Answer: 9**

Solution: $V = \frac{g\omega t^2}{2}$

$$\frac{V_2}{V_1} = \left(\frac{t_2}{t_1}\right)^2 = \left(\frac{3}{1}\right)^2 = 9$$

#### 2.2.3

Find the angle of inclination of the board at which the speed of the bar will be 3 $m/s$. Give your answer in degrees and round to tenths. Take the free fall acceleration equal to 10 $m/s^2$. The movement of the bar occurs in one vertical plane. The bar moves at a small distance from the axis of rotation of the board, so consder the non-inertial frame of reference associated with the board at a given value of the angular velocity to be negligible. Consider the air resistance to be negligible.

Note: for small $\alpha$, $sin(\alpha) \approx \alpha$ .

**Answer: 5.9**

Solution: $V = \frac{g\alpha^2}{2\omega}$

$$\alpha \approx \sqrt{\frac{2\,\omega V}{g}} \approx \sqrt{2 \cdot rad\frac{1^\circ \cdot 3}{10}} = 5.9^\circ$$

## 2.3 Task

A sealed heat-conducting vessel, closed by a sealed movable piston, is filled with moist air with a relative humidity of 40 % at a pressure of 50 $kPa$.

#### 2.3.1

By how many times must the volume of the vessel be reduced in order for water vapor to condense inside? Give your answer to the nearest tenth.

**Answer: 2.5**

Solution: $n\varphi = 1 \Rightarrow n = \frac{1}{\varphi} = \frac{1}{0.4} = 2.5$

#### 2.3.2

Find the ratio of the initial density of water vapor to the density of water vapor at a volume 5 times less than the initial one. Give your answer to the nearest tenth.

**Answer: 0.4**

Solution: At start $(V)$

$$P_S V = \frac{m}{\mu}RT;\ P_S = \frac{\rho_S}{\mu}RT;\ \rho_S = \frac{\mu P_S}{RT} = \frac{\mu \cdot \varphi P_S}{RT}$$

At finish $\left(\frac{V}{5}\right)$

$$\rho_{\Pi}{}' = \frac{\mu P_S}{RT}$$

$$\left(\frac{\rho_S{}'}{\rho_S}\right)^{-1} = 0.4$$

#### 2.3.3

Find the ratio of the pressure of moist air in the vessel with a volume 5 times less than the initial one to the initial pressure of moist air in the vessel. Give your answer to the nearest integer. The contents of the vessel are kept at a temperature of $100°C$ all the time. Consider the volume of condensed water to be negligible. Take saturated vapor pressure at a temperature of $100°C$ equal to 100 $kPa$.

**Answer: 3**

Solution: Pressure at start

$$P = P_{dry} + P_{sat};\ P_{dry} = (P - \varphi P_{sat})$$

Pressure at finish

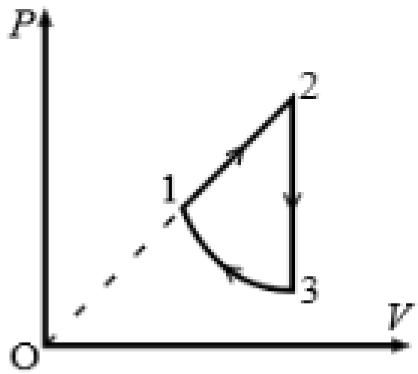
$$P_f = 5P_{dry} + P_{sat} = 5(P - \varphi P_{sat}) + P_{sat} = 5P - 5\varphi P_{sat} + P_{sat} = 5P - P_{sat}(5\varphi - 1)$$

$$\frac{P_f}{P} = 5 - \frac{P_{sat}}{P}(5\varphi - 1) = 5 - \frac{100}{50}(5 \cdot 0.4 - 1) = 3$$

### 2.4 Task

#### 2.4.1

Find the ratio of the change in the internal energy of the gas to the work done by the gas in process 1-2. Give your answer to the nearest integer.




**Answer: 3**

Solution: $\Delta U_{12} = \dfrac{3}{2}\nu R(T_2 - T_1)$

$$A_{12} = \frac{1}{2}(P_2 + P_1)(V_2 - V_1) = \frac{1}{2}\nu R(T_2 - T_1)$$

$$\frac{\Delta U_{12}}{A_{12}} = 3$$

#### 2.4.2

Find the ratio of the amount of heat received by the gas in process 1-2 to the amount of heat given off by the gas in process 2-3. Give your answer to the nearest tenth.

**Answer: 1.3**

Solution: $Q_{12} = \Delta U_{12} + A_{12} = 2(T_2 - T_1)$

$$Q_{23} = \frac{3}{2}\nu R(T_2 - T_1) \Rightarrow \frac{Q_{12}}{Q_{23}} = \tfrac{4}{3} \approx 1.3$$

#### 2.4.3

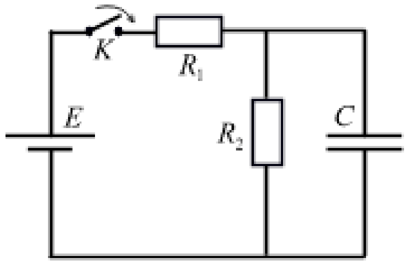
Find the molar heat capacity of the gas in process 1-2. Give your answer to the nearest tenth.

**Answer: 16.6**

Solution: $C = 2R = 2 \cdot 8.31 \approx 16.6\ \dfrac{J}{mol \cdot K}$

## 2.5 Task

The electrical circuit, shown in the figure consists a battery with an EMF 40 $V$, two resistors with a resistance of $R_1 = 10\ ohms$, $R_2 = 20\ ohms$ and a capacitor with a capacitance of 100 $\mu F$. Initially the switch K is open. Then the switch K is closed




### 2.5.1

Find the current through the source immediately the switch K is closed. Give your answer in A to the nearest integer.

**Answer: 4**

Solution: $I = \dfrac{\varepsilon}{R_1} = \dfrac{40}{10} = 4\ A$

### 2.5.2

Find the current through the capacitor at the time when the voltage across the capacitor is 10 $V$. Give the answer in $A$ to the nearest tenth.

**Answer: 2.5**

Solution: $I_2 \cdot R_2 = U_2 \Rightarrow I_2 = \dfrac{U_2}{R_2} = \dfrac{10}{20} = 0.5\ A$

Voltage across $R_1$: $U_1 = E - U_2 = 30\ V$

Current through $R_1$: $I_1 = \dfrac{U_1}{R_1} = \dfrac{30}{10} = 3\ A$

$I_1 = I_2 + I_c \Rightarrow I_c = I_1 - I_2 = 3 - 0.5 = 2.5\ A$

### 2.5.3

Find the rate of change of the current flowing through the resistance $R_2$ at the time when the voltage across the capacitor is 10 $V$. Give the answer in $A/s$ to the nearest integer.

Consider the internal resistance of EMF to be negligible.

**Answer: 1250**

Solution: $I_2 \cdot R_2 = \dfrac{q}{c}$

$$\frac{\Delta I_2}{\Delta t} = \frac{I_C}{CR_2} = \frac{2.5}{100 \cdot 10^{-6} \cdot 20} = 1250\ A/s$$

# 3 Round

## 3.1 Task

The ball, being at a height H, starts moving with an initial speed of 10 m/s, directed parallel to the horizontal surface of the earth. For the last 0.1 seconds before hitting the ground, the ball was at a height $h = \frac{1}{7}H$.

### 3.1.1

Find the flight time of the ball from the moment it starts moving until it hits the ground. Give your answer in seconds and round to the nearest tenth.

**Answer: 1.3**

Solution: $T = \dfrac{\tau}{1 - \sqrt{1 - \dfrac{1}{7}}} = \dfrac{0.1}{1 - \sqrt{1 - \dfrac{1}{7}}} \approx 1.3\ s$

### 3.1.2

Find the modulus of the ball's speed when it hits the ground. Give your answer in $m/s$ and round to the nearest integer.

**Answer: 17**

Solution: $V_x = 10\ m/s$; $V_y \approx 13\ m/s$

$$V = \sqrt{V_x^2 + V_y^2} \approx \sqrt{10^2 + 13^2} \approx 17\ m/$$

### 3.1.3

Find the maximum radius of curvature of the ball's flight trajectory. Give your answer in meters and round to the nearest integer.

Take the free fall acceleration equal to 10 $m/s^2$. Neglect air resistance.

**Answer: 47**

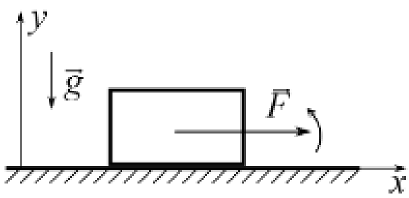
Solution: $tan(\alpha) \approx \dfrac{V_y}{V_x} \approx 1.3$

$$a_n = g \cdot cos(\alpha) = g\frac{1}{\sqrt{1 + tan^2(\alpha)}} = \sqrt{\frac{10}{\sqrt{1 + 1.3^2}}} \approx\ m/s^2$$

$$R = \frac{V^2}{a_n} \approx \frac{16.8^2}{6} \approx 47\ m$$

## 3.2 Task

A force of 3 $N$ is applied to a 2 $kg$ bar lying on a horizontal rough surface. The direction of the force vector, initially directed along the horizontal surface, rotates at an angular velocity of 5 degrees per second. The coefficient of friction of the bar on the surface is 0.1. Acceleration of gravity take equal to 10 $m/s^2$.




### 3.2.1

Find the acceleration of the bar at the initial moment of time. Give your answer in $m/s^2$ to the nearest tenth.

**Answer: 0.5**

Solution: $ma = F = \mu mg \Rightarrow ma = 1$

$a = 0.5\ m/s^2$

### 3.2.2

Find the minimum time after which the block starts to slow down. Give your answer in seconds and round to the nearest integer.

**Answer: 10.8**

Solution: $a = 0$; $F \cdot cos(\alpha) - \mu(mg - F\,sin(\alpha)) = 0$

$Fcos(\alpha) + \mu\,sin(\alpha)) = \mu mg \Rightarrow 0.3sin(\alpha) + 3cos(\alpha) = 2$

$cos(\alpha - \varphi) = \dfrac{2}{\sqrt{0.3^2 + 3^2}} cos(\varphi) = \dfrac{3}{\sqrt{0.3^2 + 3^2}} \Rightarrow \alpha \approx 54.15°$

$\omega\tau \approx 54.15°$; $\tau \approx 10.8\ c$

### 3.2.3

Find by what percentage the maximum acceleration is greater than the acceleration of the bar at the initial moment of time. Round your answer to tenths.

**Answer: 1.5**

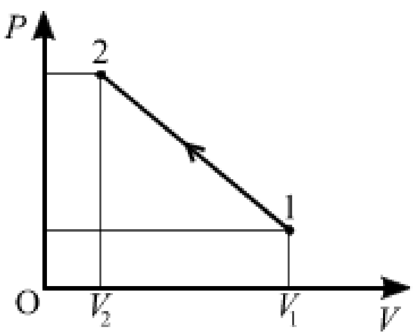
Solution: Acceleration is maximum at $tan(\alpha) = \mu$; $ma_m = F(cos(\alpha) + \mu\,sin(\alpha)) - \mu mg \Rightarrow$

$$a_m = \frac{F}{m}\left(\sqrt{\frac{1}{1 + tan^2(\alpha)}} + \sqrt{\frac{1}{1 + \dfrac{1}{tan^2(\alpha)}}}\right) - \mu g = \frac{3}{2}\sqrt{\frac{1}{1 + 0.1^2} + 0.1\sqrt{\frac{1}{1 + 0.1^2}}} - 0.1 \cdot 10 \approx$$
$$\approx 0.507\ m/s^2$$

$\dfrac{a_m - a}{a} \approx 1.5\%$

## 3.3 Task

One mole of helium undergoes a process 1-2 shown in the figure. The gas temperature at points 1 and 2 is the same and is equal to $T_0 = 300\ K$. The ratio of volume $V_1$ to volume $V_2$ is 4.




### 3.3.1

Find the pressure ratio $\dfrac{P_2}{P_1}$. Give your answer to the nearest integer.

**Answer: 4**

Solution: $\dfrac{P_2V_2}{P_1V_1} = 1 \Rightarrow \dfrac{P_2}{P_1} = \dfrac{V_1}{V_2} = 4$

### 3.3.2

Find the ratio of the internal energy at point 1 to the modulus of work done by the gas in the process. Give your answer to the nearest tenth.

**Answer: 0.8**

Solution: $A = \frac{1}{2}RT_0\left(\frac{n^2-1}{n}\right)$; $U = \frac{3}{2}RT_0$

$$\left(\frac{U}{A}\right) = \left(\frac{3n}{n^2-1}\right) = \left(\frac{3\cdot 4}{16-1}\right) = 0.8$$

#### 3.3.3

Find the ratio of the maximum value of the internal energy of the gas to the minimum in this process. Give your answer to the nearest tenth.

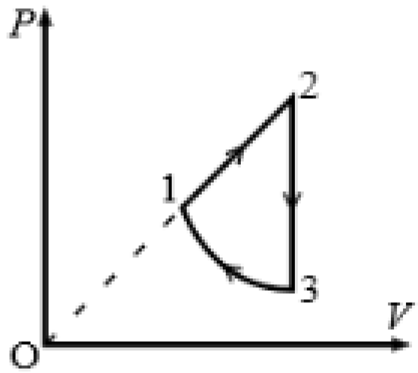
**Answer: 1.6**

Solution: $\frac{U_{max}}{U_0} = \frac{(n+1)^2}{4n} = \frac{(4+1)^2}{4\cdot 4} \approx 1.6$

## 3.4 Task

One mole of monoatomic ideal gas undergoes a cyclic process 1-2-3 shown in the figure. In process 1–2, the gas expands so that the pressure increases in direct proportion to the volume. In process 2-3, the gas pressure decreases isochorically. In process 3-1, the volume of the gas decreases isothermally. The minimum temperature in the cyclic process is 200 $K$.

The ratio of the maximum volume occupied by the gas in the cyclic process to the minimum is 1.5. The amount of heat removed from the gas in process 3-1 is 674 $J$.




Take the universal gas constant equal to 8.31 $\frac{J}{mol\cdot K}$.

#### 3.4.1

Find the maximum gas temperature in the cyclic process. Give your answer in $K$ to the nearest integer.

**Answer: 450**

Solution: $P = \alpha V$; $PV = \alpha V^2$; $RT = \alpha V^2$

$$\frac{T_{max}}{T_{min}} = \frac{V_2^2}{V_1^2} = 2.25;\ T_{max} = 2.25;\ T_{min} = 450\ K$$

#### 3.4.2

Find the ratio of the maximum pressure in the cyclic process to the minimum. Round your answer to tenths.

**Answer: 2.3**

Solution: $\frac{P_2}{P_3} = 2.3$

#### 3.4.3

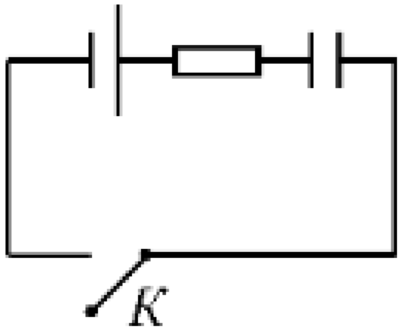
Find the cycle efficiency. Give your answer as a percentage and round to tenths.

**Answer: 8.8**

Solution: $\eta = \frac{A_y}{Q_н} = \frac{\frac{1}{2}\nu R(T_{max} - T_{min}) - Q_{31}}{2\nu R(T_{max} - T_{min})} = \frac{\frac{1}{2} \cdot 8.31(450 - 200) - 674}{2 \cdot 8.31 \cdot (450 - 200)} \approx 8.8\%$

## 3.5 Task

In the electrical circuit shown in figure the switch K is initially open, the capacitor is not initially charged. The source EMF is 8 $V$. The resistance of the resistor is 2 $ohms$, the capacitance of the capacitor is 2 $\mu F$. The area of the capacitor plates is 2 $m^2$. Then the switch K is closed. Take the value of the electrical constant equal to 8,85$\cdot 10^{-12}$ $F/m$.




### 3.5.1

Find the voltage across the resistor immediately after the switch is closed. Give your answer in volts to the nearest integer.

**Answer: 8**

Solution: $U_0 = \varepsilon = 8\ V$

### 3.5.2

Find the ratio of the amount of heat released across the resistor for the entire time after the switch is closed to the energy of a fully charged capacitor (capacitor energy, a long time after the switch is closed). Give your answer to the nearest integer.

**Answer: 1**

Solution: $\frac{Q}{W} = 1$

### 3.5.3

Find the force acting on capacitor plates at the time when the current in the circuit is half the maximum. Give your answer in N and round to the nearest tenth.

**Answer: 1.8**

Solution: $C = \frac{\varepsilon_0 S}{d}$; $d = \frac{\varepsilon_0 S}{C}$

$F = \frac{Cu^2}{2d}$; $U = \varepsilon - IR = \varepsilon - \frac{\varepsilon R}{2R} = \frac{\varepsilon}{2}$

$F = \frac{C^2\varepsilon^2}{8d} = \frac{C^2\varepsilon^2}{8\varepsilon_0 S} = \frac{(2 \cdot 10^{-6})^2 \cdot 8}{8 \cdot 8.85 \cdot 10^{-12} \cdot 2} \approx 1.8\ N$

# 4 тур

## 4.1 Task

A small ball is dropped from a height of 1 meter onto a long, frictionless, inclined surface. After an elastic collision, the ball bounces off the surface. Take the free fall acceleration equal to 10 $m/s^2$.

### 4.1.1

Find the modulus of the speed with which the ball bounces off the surface first time. Give your answer in $m/s$ and round to the nearest tenth.

**Answer: 4.5**

Solution: $V_0 = \sqrt{2gH} = \sqrt{20} = 4.5\ m/s$

### 4.1.2

Find the time after which the ball hits the surface a second time. Give your answer in seconds and round to the nearest tenth.

**Answer: 0.9**

Solution: $T = 2\sqrt{\frac{2H}{g}} = 2 \cdot \sqrt{\frac{2}{10}} \approx 0.9\ s$

### 4.1.3

Find the angle of inclination of the surface to the horizon, under which you need to position the surface so that the ball hits the second time at a distance of 1 meter from the point of initial collision (the distance is measured along the plane). Give your answer in degrees and round to tenths.

**Answer: 7.2**

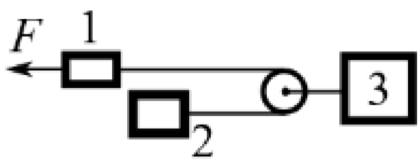
Solution: $L = V_0 \cdot sin(\alpha)T + \frac{g\,sin(\alpha)\,T^2}{2} = V_0 \cdot sin(\alpha) \cdot 2\sqrt{\frac{2H}{g}} + \frac{g\ sin(\alpha)}{2}\frac{4 \cdot 2\,H}{g} = 2\ sin(\alpha)\left(V_0\sqrt{\frac{2H}{g}} + 2H\right)$

$$sin(\alpha) = \frac{L}{2\left(V_0\sqrt{\frac{2H}{g}} + 2H\right)} = \frac{L}{2(2H + 2H)} = \frac{L}{8H} = \frac{1}{8}$$

$\alpha \approx 7.2°$

## 4.2 Task

In the system of bodies shown in the figure (top view), a force of 12 $N$ is applied to the first bar. All bars lie on a smooth horizontal surface. The line of action of the force, sections of the thread connecting the first and second bars, as well as the thread connecting the third bar with the block, are parallel. The mass of the first bar is 1 $kg$, the mass of the second bar is 2 $kg$, and the mass of the third bar is 3 $kg$.



### 4.2.1

Find the acceleration modulus of the center of mass of the system of bodies. Give your answer in $m/s^2$ to the nearest integer.

**Answer: 2**

Solution: $a = \dfrac{F}{m_1 + m_2 + m_3} = \dfrac{12}{1+2+3} = 2\ m/s^2$

### 4.2.2

Find the acceleration of the bar 1. Give your answer in $m/s^2$ and round to the nearest tenth.

**Answer: 7.8**

Solution: $a_3 = \dfrac{2m_2\ F}{4m_1m_2 + m_3(m_1+m_2)} = \dfrac{2\cdot 2\cdot 12}{4\cdot 1\cdot 2 + 3(1+2)} = \dfrac{48}{17} \approx 2.8\ m/s^2$

$a_{rel} = \dfrac{(2m_2+m_3)F}{4m_1m_2 + m_3(m_1+m_2)} = \dfrac{(2\cdot 2+3)12}{4\cdot 1\cdot 2 + 3(1+2)} = \dfrac{84}{17} \approx 4.9\ m/s^2$

$a_1 = a_3 + a_{rel} \approx 7.8\ m/s^2$

### 4.2.3

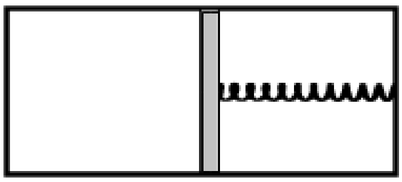
Find the tension in thread connecting the bar 1 and the bar 2. Give your answer in $N$ and round to the nearest tenth. Neglect the masses of the threads, the block, as well as the friction in the axis of the block. Threads are considered inextensible.

**Answer: 4.2**

Solution: $2T = m_3a_3$; $T = \dfrac{m_3a_3}{2}\dfrac{3\cdot 48}{2\cdot 17} \approx 4.2\ N$

## 4.3 Task

The horizontally placed sealed cylinder is divided into two parts by a movable piston, which can move along the cylinder without friction. In one part of the cylinder is nitrogen (N2) at a temperature of 300 $K$, in the other part is vacuum.



The piston is connected to the vertical wall of the cylinder by a spring located in the vacuum part of the cylinder.

The spring is selected so that in the undeformed state of the spring, the piston is located at the left wall of the vessel. The gas is slowly heated to a certain temperature. In this process, the volume of gas increases by 1.5 times.

### 4.3.1

Find the ratio of the final pressure to the initial one. Give your answer to the nearest tenth.

**Answer: 1.5**

Solution: $\dfrac{P_2}{P_1} = n = 1.5$

### 4.3.2

Find how much the temperature of nitrogen changed during heating (the difference between final temperature and the initial temperature). Give your answer in $^\circ C$ and round to the nearest integer.

**Answer: 375**

Solution: $\Delta T = T_2 - T_1 = (n^2 - 1)T_1 = 1.25 \cdot 300 = 375°C$

#### 4.3.3

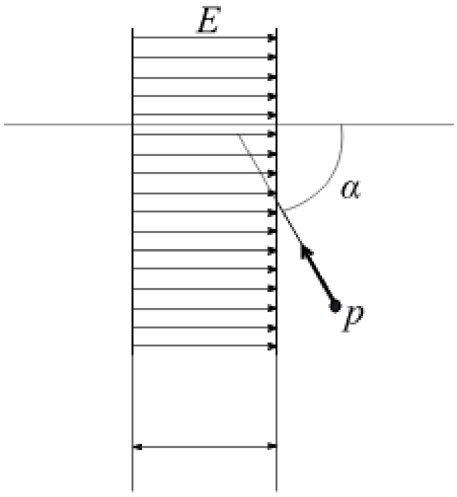
Find the ratio of the heat received by the gas to the work done by the gas in this process. Give your answer to the nearest integer.

**Answer: 6**

Solution: $\dfrac{Q}{A} = \dfrac{3\nu R\Delta T}{\frac{1}{2}\nu R\Delta T} = 6$

## 4.4 Task

A proton moving at a speed of 100 $km/s$ flies into a region of a uniform electric field 1 $m$ wide and 10 $V/m$ at an angle of 60° to field lines. Take the ratio of the proton charge to its mass equal to $9{,}6 \cdot 10^7$ $C/kg$.




#### 4.4.1

Find the radius of curvature of the proton's trajectory immediately after entering the region of a uniform electric field. Give your answer in meters and round to the nearest integer.

**Answer: 12**

Solution: $R = \dfrac{V_0^2}{\frac{q}{m}E \cdot sin(\alpha)} = \dfrac{(1 \cdot 10^5)^2}{9.6 \cdot 10^7 \cdot 10\ sin(60°)} \approx$
$\approx 12\ m$

#### 4.4.2

Find the modulus of the difference between the maximum and minimum proton speeds when moving in a region of a uniform electric field. Give your answer in $km/s$ and round to the nearest integer.

**Answer: 10**

Solution: because of $d < \dfrac{(V_0 cos(\alpha))^2}{2a} \approx 1.3\ m$; $ma = qE$; $a = \dfrac{q}{m}E = 9.6 \cdot 10^8\ m/s^2$

$$t = \frac{V_0 cos(\alpha) - \sqrt{(V_0 cos(\alpha))^2 - 2ad}}{a} = \frac{1 \cdot 10^5 \cdot cos(60°) - \sqrt{(1 \cdot 10^5 \cdot cos(60°))^2 - 2 \cdot 9.6 \cdot 10^8 \cdot 1}}{9.6 \cdot 10^8} \approx$$

$\approx 2.7 \cdot 10^{-5} \Rightarrow V_x = V_0 \cdot sin(\alpha)$; $V_y = V_0 \cdot cos(\alpha) - at$

$|V| = \sqrt{(V_0 sin(\alpha))^2 + (V_0 \cdot cos(\alpha) - at)^2} \approx 90\ km/s$; $|V - V_0| \approx 10\ km/s$

#### 4.4.3

Find the angle by which the proton's momentum vector will rotate during its movement in the region of a uniform electric field. Give your answer in degrees and round to the nearest integer.

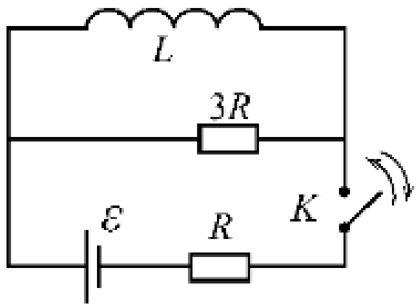
Neglect the effects of gravity.

**Answer: 14**

Solution: $tan(\beta) = \dfrac{V_x}{V_y}$; $\beta \approx 74°$; $\beta - \alpha \approx 74° - 60° = 14°$

## 4.5 Task

In the electrical circuit shown in figure the switch K is initially open, EMF is 12 $M$, $R = 1\ ohm$, $L = 50\ mH$. Then switch K is closed. After all the currents have ceased to change (the mode in the circuit has been established), the key K is opened.




### 4.5.1

Find the current across the resistance 3R immediately after the switch is closed. Give your answer in $A$ to the nearest integer.

**Answer: 3** Solution: $I = \dfrac{\varepsilon}{R+3R} = \dfrac{12}{1+3} = 3\ A$

### 4.5.2

Find the rate of change of current through the inductor immediately after the switch is closed. Give your answer in $A/s$ to the nearest integer.

**Answer: 180**

Solution: $L\dfrac{\Delta I}{\Delta t} + IR = \varepsilon$

$$\left|\frac{\Delta I}{\Delta t}\right| = \frac{\varepsilon - IR}{L} = \frac{12 - 3 \cdot 1}{50 \cdot 10^{-3}} \approx 180\ A/s$$

### 4.5.3

Find the charge flowed through the resistance 3R for the entire time after the switch is opened. Give your answer in C to the nearest tenth.

**Answer: 0.2**

Solution: $-L\dfrac{\Delta I}{\Delta t} + IR = 3RI = 3R\dfrac{\Delta q}{\Delta t}$; $-L(0 - I_1) = 3R(q - 0)$

$I_1 = \dfrac{\varepsilon}{R} = 12\ A$; $LI_1 = 3Rq$

$$q = \frac{LI_1}{3R} = \frac{L\varepsilon}{3R^2} = \frac{50 \cdot 10^{-3} \cdot 12}{3 \cdot 1^2} = 0.2\ C$$