MINISTERY OF EDUCATION OF THE REPUBLIC OF BELARUS

EDUCATIONAL ESTABLISHMENT
«BREST STATE TECHNICAL UNIVERSITY»

DEPARTMENT OF PHYSICS

SOME PROBLEMS TO SOLVE AT PRACTICAL CLASSES IN PHYSICS

«Mechanics and Molecular Physics»

Brest 2020

UDC 536.35 (0765)

The methodical instructions presented here are compiled in accordance with the curriculum of physics course. The guidance aims to facilitate students understanding of various physical processes in Mechanics and Molecular Physics. The instructions are meant for students of all technical specialties and forms of studies at Brest State Technical University.

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Problem № 1. Motion in Two Dimensions

The position vector of a material point is described by the equation $\vec{r} = \vec{r}(t)$, where **i** and **j** are unit vectors.

1. Determine the velocity components;
2. Calculate magnitude of velocity at time t_1;
3. Determine the acceleration components;
4. Calculate magnitude of acceleration at time t_1;
5. Make a graph of the object's path.

Data Table

№	$\vec{r} = \vec{r}(t)$	t_1, s
1	$\mathbf{r} = 2t\cdot\mathbf{i} + 6t^2\cdot\mathbf{j}$	1.5
2	$\mathbf{r} = t\cdot\mathbf{i} + 5.5t^2\cdot\mathbf{j}$	3.0
3	$\mathbf{r} = 4t\cdot\mathbf{i} + 48t^2\cdot\mathbf{j}$	0.5
4	$\mathbf{r} = 3t\cdot\mathbf{i} + 18t^2\cdot\mathbf{j}$	1.0
5	$\mathbf{r} = 3t^2\cdot\mathbf{i} + 5t^2\cdot\mathbf{j}$	2.0
6	$\mathbf{r} = 2t^2\cdot\mathbf{i} + 4t^2\cdot\mathbf{j}$	3.0
7	$\mathbf{r} = 2t^2\cdot\mathbf{i} + 3t^2\cdot\mathbf{j}$	0.5
8	$\mathbf{r} = 4t^2\cdot\mathbf{i} + 6t^2\cdot\mathbf{j}$	0.2
9	$\mathbf{r} = 16t^2\cdot\mathbf{i} - 12t\cdot\mathbf{j}$	0.1
10	$\mathbf{r} = 4t^2\cdot\mathbf{i} - 7t\cdot\mathbf{j}$	4.0
11	$\mathbf{r} = 9t^2\cdot\mathbf{i} - 15t\cdot\mathbf{j}$	2.0
12	$\mathbf{r} = 25t^2\cdot\mathbf{i} - 7.5t\cdot\mathbf{j}$	0.4
13	$\mathbf{r} = 1.5t\cdot\mathbf{i} - 5t^2\cdot\mathbf{j}$	1.0
14	$\mathbf{r} = 2t\cdot\mathbf{i} - 6t^2\cdot\mathbf{j}$	2.0
15	$\mathbf{r} = 0.5t\cdot\mathbf{i} - 2t^2\cdot\mathbf{j}$	0.5
16	$\mathbf{r} = 3t\cdot\mathbf{i} - 4.5t^2\cdot\mathbf{j}$	5.0
17	$\mathbf{r} = 36t^2\cdot\mathbf{i} + 12t\cdot\mathbf{j}$	0.3
18	$\mathbf{r} = 16t^2\cdot\mathbf{i} + 16t\cdot\mathbf{j}$	0.6
19	$\mathbf{r} = 9t^2\cdot\mathbf{i} + 3t\cdot\mathbf{j}$	0.8
20	$\mathbf{r} = 4t^2\cdot\mathbf{i} + 5t\cdot\mathbf{j}$	3.0
21	$\mathbf{r} = 0.2t^2\cdot\mathbf{i} - 1.2t^2\cdot\mathbf{j}$	2.0
22	$\mathbf{r} = 1.5t^2\cdot\mathbf{i} - 3t^2\cdot\mathbf{j}$	2.5
23	$\mathbf{r} = 0.5t^2\cdot\mathbf{i} - 2t^2\cdot\mathbf{j}$	1.5
24	$\mathbf{r} = 2t^2\cdot\mathbf{i} - 5t^2\cdot\mathbf{j}$	0.2
25	$\mathbf{r} = 0.4t\cdot\mathbf{i} + 2t\cdot\mathbf{j}$	0.25
26	$\mathbf{r} = 2.5t\cdot\mathbf{i} + 5t\cdot\mathbf{j}$	4.0
27	$\mathbf{r} = 3t\cdot\mathbf{i} + 4.5t\cdot\mathbf{j}$	1.3
28	$\mathbf{r} = 8t\cdot\mathbf{i} + 20t\cdot\mathbf{j}$	1.7

Problem № 2. Motion in Two Dimensions

The coordinates of an object are given as equations $x=x(t)$ and $y=y(t)$.
1. Determine the magnitude of total acceleration at time t_1;
2. Determine the magnitude of tangential acceleration at time t_1;
3. Determine the magnitude of normal acceleration at time t_1;
4. Calculate the radius of curvature at a given point of the trajectory.

Data Table

№	*x(t)*	*y(t)*	t_1, s
1	$x = 2t - t^3$	$y = t^2 + 2t^3$	0.2
2	$x = 2t - t^3$	$y = t^2 + 2t^3$	0.4
3	$x = 2t - t^3$	$y = t^2 + 2t^3$	0.6
4	$x = 2t - t^3$	$y = t^2 + 2t^3$	0.8
5	$x = 2t + 3t^2$	$y = 24 - 4t^3$	0.1
6	$x = 2t + 3t^2$	$y = 24 - 4t^3$	0.3
7	$x = 2t + 3t^2$	$y = 24 - 4t^3$	0.8
8	$x = 2t + 3t^2$	$y = 24 - 4t^3$	1.0
9	$x = 34 - t + 2t^3$	$y = 5t - t^2$	0.6
10	$x = 34 - t + 2t^3$	$y = 5t - t^2$	0.8
11	$x = 34 - t + 2t^3$	$y = 5t - t^2$	1.0
12	$x = 34 - t + 2t^3$	$y = 5t - t^2$	1.2
13	$x = 0.5t^2 + 3t$	$y = 15 - 4t + 1.5t^3$	1.2
14	$x = 0.5t^2 + 3t$	$y = 15 - 4t + 1.5t^3$	1.3
15	$x = 0.5t^2 + 3t$	$y = 15 - 4t + 1.5t^3$	1.4
16	$x = 0.5t^2 + 3t$	$y = 15 - 4t + 1.5t^3$	1.5
17	$x = 11 + t^2 - 0.5t^3$	$y = 7 - 2.5t^3$	0.3
18	$x = 11 + t^2 - 0.5t^3$	$y = 7 - 2.5t^3$	0.3
19	$x = 11 + t^2 - 0.5t^3$	$y = 7 - 2.5t^3$	0.4
20	$x = 11 + t^2 - 0.5t^3$	$y = 7 - 2.5t^3$	0.5
21	$x = -6 + 0.1t^3$	$y = 0.2t^3 - 2t^2$	5.0
22	$x = -6 + 0.1t^3$	$y = 0.2t^3 - 2t^2$	4.0
23	$x = -6 + 0.1t^3$	$y = 0.2t^3 - 2t^2$	3.0
24	$x = -6 + 0.1t^3$	$y = 0.2t^3 - 2t^2$	2.0
25	$x = 5 + 2t + 1.5t^2$	$y = 18 + 0.25t^3$	1.0
26	$x = 5 + 2t + 1.5t^2$	$y = 18 + 0.25t^3$	1.1
27	$x = 5 + 2t + 1.5t^2$	$y = 18 + 0.25t^3$	1.2
28	$x = 5 + 2t + 1.5t^2$	$y = 18 + 0.25t^3$	1.3

Problem № 3. Motion with Acceleration in One Dimension

A material point moves from rest in the direction parallel to axis OX with changing acceleration described by the equation $a = A + Bt + Ct^2$, where A, B, C are constants. Let the origin be at the point of release, let t=0 correspond to the instant of release.

1. Write expressions for $\boldsymbol{V}_x$, $\boldsymbol{V}_y$, x and y as functions of time;
2. Determine the speed of the material point at time t_1;
3. Determine the path length of the material point at time t_1.

Data Table

№	A, m/s^2	B, m/s^3	C, m/s^4	t_1, s
1	1	–2	2	2.5
2	8	4	14	0.4
3	16	9	–5	1.2
4	4	–6	11	0.8
5	10	–3	13	0.75
6	22	–14	–6	2.0
7	12	18	15	0.4
8	8	7	–3	1.5
9	2	–5	4	0.9
10	17	–20	7	1.6
11	6	–10	8	0.5
12	9	4	19	0.3
13	8	–1	16	1.5
14	10	7	–3	2.0
15	18	–11	9	0.6
16	–2	20	14	0.5
17	2	–6	11	1.7
18	19	15	5	1.0
19	15	–3	18	0.8
20	12	20	–4	1.5
21	5	–7	13	0.7
22	12	–19	1	0.4
23	16	9	20	0.9
24	–3	–1	10	1.6
25	–6	3	12	1.8
26	17	–14	5	1.3
27	9	8	–15	0.6
28	7	10	–1	1.2

Problem № 4. Motion in Three Dimensions

Two material points begin moving from initial points (*0;0;0*) relative to the origin of reference frame. From algebraic signs $\boldsymbol{V_1}(t)$, $\boldsymbol{V_2}(t)$, where ***i, j, k*** are unit vectors:

1. Write expressions *x*, *y* and *z* as functions of time;
2. Determine the distance between the material points at time t_1.

Data Table

<table>
<tr><th>№</th><th>$\boldsymbol{V_1}(t)$, m/s</th><th>$\boldsymbol{V_2}(t)$, m/s</th><th>t_1, s</th></tr>
<tr><td>1</td><td rowspan="4">$\vec{V}_1 = 5t \cdot \vec{i} + 2t^2 \cdot \vec{j} + 3 \cdot \vec{k}$</td><td rowspan="4">$\vec{V}_2 = 4 \cdot \vec{i} + t \cdot \vec{j} + 2t^2 \cdot \vec{k}$</td><td>1.0</td></tr>
<tr><td>2</td><td>2.0</td></tr>
<tr><td>3</td><td>3.0</td></tr>
<tr><td>4</td><td>4.0</td></tr>
<tr><td>5</td><td rowspan="4">$\vec{V}_1 = 9t^2 \cdot \vec{i} - \vec{j} + 2 \cdot \vec{k}$</td><td rowspan="4">$\vec{V}_2 = 2t \cdot \vec{i} + 6t^2 \cdot \vec{k}$</td><td>1.0</td></tr>
<tr><td>6</td><td>1.5</td></tr>
<tr><td>7</td><td>2.0</td></tr>
<tr><td>8</td><td>2.5</td></tr>
<tr><td>9</td><td rowspan="4">$\vec{V}_1 = -1{,}2t^2 \cdot \vec{j} + 3t^2 \cdot \vec{k}$</td><td rowspan="4">$\vec{V}_2 = 6t^2 \cdot \vec{i} + 4t \cdot \vec{j} - \vec{k}$</td><td>0.5</td></tr>
<tr><td>10</td><td>1.0</td></tr>
<tr><td>11</td><td>1.5</td></tr>
<tr><td>12</td><td>2.0</td></tr>
<tr><td>13</td><td rowspan="4">$\vec{V}_1 = 8t \cdot \vec{i} - 12t^2 \cdot \vec{j} + \vec{k}$</td><td rowspan="4">$\vec{V}_2 = \vec{i} - 2t \cdot \vec{j} + 3t^2 \cdot \vec{k}$</td><td>0.2</td></tr>
<tr><td>14</td><td>0.3</td></tr>
<tr><td>15</td><td>0.5</td></tr>
<tr><td>16</td><td>0.8</td></tr>
<tr><td>17</td><td rowspan="4">$\vec{V}_1 = 2t \cdot \vec{i} - 6t^2 \cdot \vec{k}$</td><td rowspan="4">$\vec{V}_2 = 4.5t^2 \cdot \vec{i} - 4t \cdot \vec{j} + 2t \cdot \vec{k}$</td><td>2.0</td></tr>
<tr><td>18</td><td>3.0</td></tr>
<tr><td>19</td><td>4.0</td></tr>
<tr><td>20</td><td>5.0</td></tr>
<tr><td>21</td><td rowspan="4">$\vec{V}_1 = -\vec{i} + 3t^2 \cdot \vec{j} - 6t \cdot \vec{k}$</td><td rowspan="4">$\vec{V}_2 = 2t \cdot \vec{i} - 9t^2 \cdot \vec{k}$</td><td>2.0</td></tr>
<tr><td>22</td><td>4.0</td></tr>
<tr><td>23</td><td>6.0</td></tr>
<tr><td>24</td><td>8.0</td></tr>
<tr><td>25</td><td rowspan="4">$\vec{V}_1 = 4t \cdot \vec{i} + 2t \cdot \vec{j}$</td><td rowspan="4">$\vec{V}_2 = 3t^2 \cdot \vec{i} - \vec{j} + 1.5t^2 \cdot \vec{k}$</td><td>0.2</td></tr>
<tr><td>26</td><td>0.4</td></tr>
<tr><td>27</td><td>0.6</td></tr>
<tr><td>28</td><td>0.8</td></tr>
</table>

Problem № 5. Kinematics of Rotation about a Fixed Axis

A material point begins rotating from rest in a circle with radius R and travels with a constant angular acceleration of magnitude ε. In a time period t after the beginning of motion, full acceleration of the point is equal to a, tangential acceleration is equal to a_τ, normal acceleration is equal to a_n. The linear and angular speeds after time t from beginning of rotation are equal to υ and ω respectively.

1. Determine the unknown values.
2. Show all vectors and pseudo vectors in your figure.

Data Table

№	R, m	ε, rad/s^2	t, s	a, m/s^2	a_n, m/s^2	a_τ, m/s^2	ω, rad/s	υ, m/s
1	0.2	1.5	0.5	?	?	?	?	?
2	?	1.0	1.2	?	?	0.4	?	?
3	?	?	?	19	?	?	4.8	3.6
4	?	?	?	?	?	1.2	0.4	2.2
5	4.0	2.6	?	?	?	?	?	2.8
6	?	3.2	0.8	?	?	?	?	3.84
7	?	?	?	7.6	0,9	?	2.4	?
8	?	?	1.0	?	?	5.4	0.6	?
9	5.0	?	2.0	?	?	?	0.68	?
10	?	4.0	1.5	?	7.2	?	?	?
11	?	?	?	6.0	?	?	1.7	1.36
12	1.0	?	?	?	1.4	4.5	?	?
13	3.0	?	?	?	?	2.8	1.5	?
14	?	0.8	?	?	?	3.0	?	4.5
15	0.6	?	3.0	?	?	?	?	0.63
16	?	?	2.5	?	?	?	1.6	1.92
17	0.8	?	1.6	?	1.15	?	?	?
18	2.5	1.0	?	5.0	?	?	?	?
19	?	?	?	?	2.0	5.5	2.0	?
20	2.5	?	?	?	?	4.0	?	2.4
21	1.5	2.0	?	?	?	?	0.8	?
22	0.3	?	0.7	?	?	?	?	0.21
23	0.7	1.8	?	4.0	?	?	?	?
24	?	0.5	?	?	2.0	?	1.2	?
25	1.5	?	?	?	?	2.6	?	3.0
26	?	?	0.4	?	0.486	?	0.9	?
27	2.0	?	?	8.0	?	5.0	?	?
28	?	2.4	0.6	?	?	2.0	?	?

Problem № 6. Kinematics of Rotation about a Fixed Axis

A disk starts rotating. Its angular speed increases from zero to ω in a time interval t after the beginning of motion. Let $t=0$ be the instant the disk begins rotating, and initial angular coordinate $\varphi_0=0\ rad$. Assuming angular acceleration ε is constant, the disk made N revolutions in a time interval t.

Determine the unknown values.

Data Table

№	t, s	ν, s^{-1}	ε, rad/s^2	N
1	10	4	?	?
2	65	?	1.353	?
3	30	?	?	150
4	?	8	2.01	?
5	?	?	3.14	4
6	?	15	?	375
7	40	6	?	?
8	25	?	1.257	?
9	15	?	?	22.5
10	?	17	1.78	?
11	?	?	4.4	8.75
12	?	20	?	800
13	50	12.5	?	?
14	20	?	1.885	?
15	75	?	?	487.5
16	?	2.5	1.047	?
17	?	?	1.396	225
18	?	5.5	?	55
19	60	12	?	?
20	35	?	2.154	?
21	55	?	?	200.75
22	?	6.5	0.628	?
23	?	?	2.513	20
24	?	9	?	135
25	6	2.5	?	?
26	70	?	0.314	?
27	45	?	?	180
28	?	8.5	1.335	?

Problem № 7. Dynamics of Translational and Rotational Motion. Work of Forces.

Blocks with masses m_1, m_2 (see Figure 7.0–7.10) are connected to each other by a light cord that passes over frictionless pulleys in the shape of a solid disk or disks having radiuses r_3, r_4 and R_4 (see Figure 7.11) and masses m_3, m_4. The cord does not slip on the pulley, and the system is released from rest. The coefficient of kinetic friction for blocks on the surfaces is μ.

1. Draw free-body diagrams of both blocks and the pulley(s).
2. Calculate the angular acceleration of the pulley(s).
3. Determine linear acceleration of the two blocks.
4. Calculate the tension in the cord on both sides of the pulley(s).
5. What is the net torque acting on the pulley(s) about its axis of rotation?
6. Determine the normal force exerted on the pulley(s) by the axle.
7. Calculate the works of all forces, which act to the blocks and to the pulley(s).
8. Find linear speeds of the blocks after block 1 (or 2) moves through a distance h (your own data), and the angular speed of the pulley(s) at this moment of time.

Data Table

№	m_1, kg	m_2, kg	m_3, kg	m_4, kg	α, deg.	μ	r_4, m	R_4, m	τ, s
0	4.0	0.50	0.5	3.0	30	0.05	0.15	0.40	0.20
1	2.5	0.25	2.0	2.8	45	0.10	0.20	0.50	0.30
2	1.0	0.10	1.5	2.9	60	0.15	0.25	0.35	0.40
3	3.5	0.40	2.5	2.5	45	0.25	0.15	0.30	0.50
4	5.0	0.60	3.0	4.2	30	0.35	0.20	0.35	0.60
5	6.0	0.75	3.5	3.2	60	0.45	0.10	0.15	0.65
6	7.0	0.80	5.5	3.4	30	0.40	0.15	0.25	0.55
7	8.0	1.0	4.0	3.6	60	0.50	0.20	0.50	0.45
8	12.0	1.5	4.5	3.8	45	0.30	0.25	0.40	0.35
9	16.0	2.0	6.,0	4.0	30	0.20	0.10	0.20	0.25

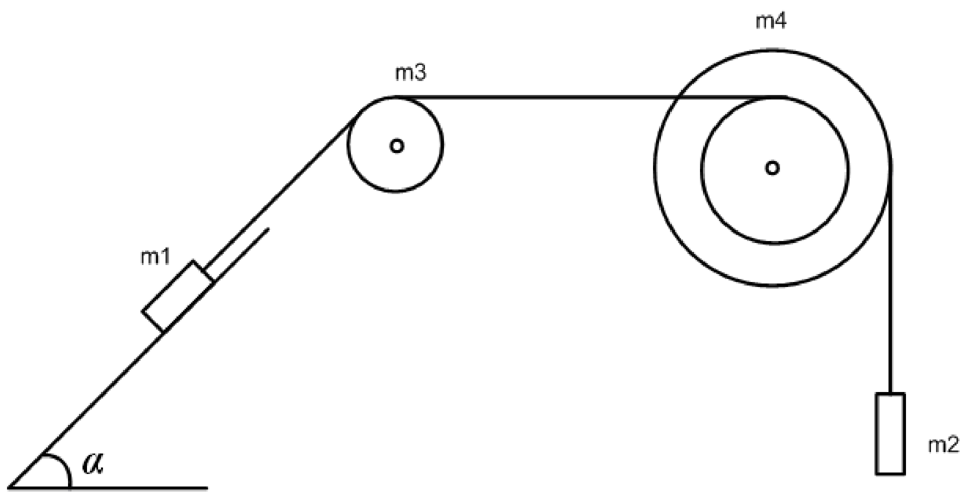


Figure 7.0

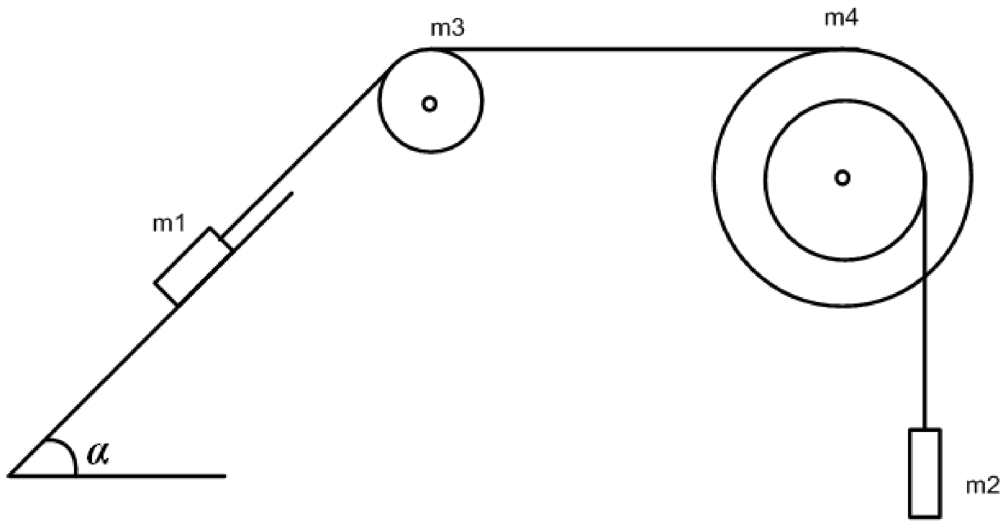


Figure 7.1

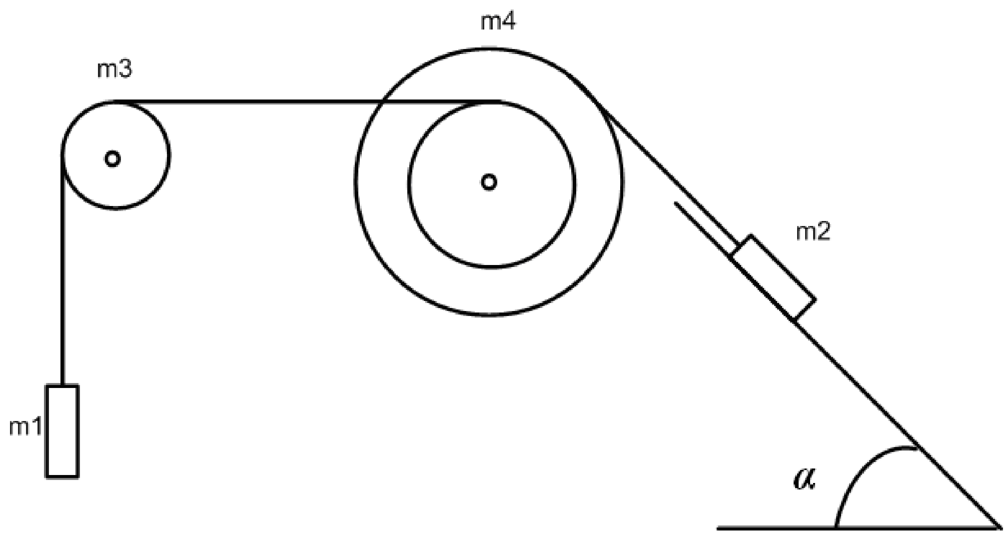


Figure 7.2

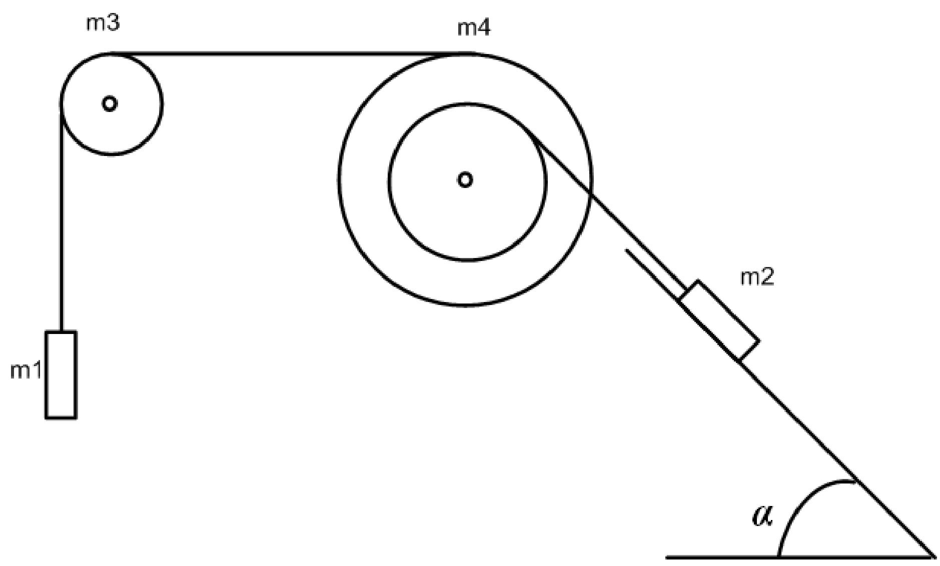


Figure 7.3

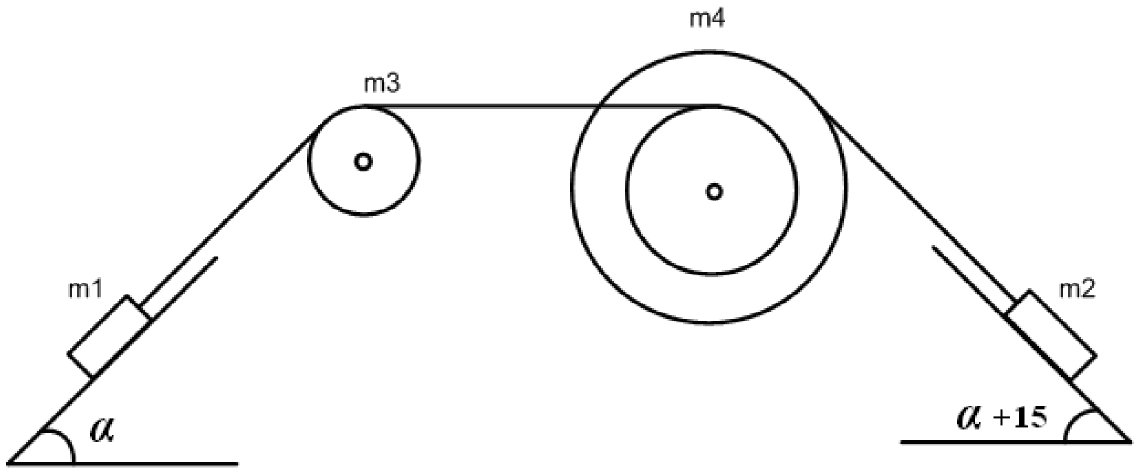


Figure 7.4

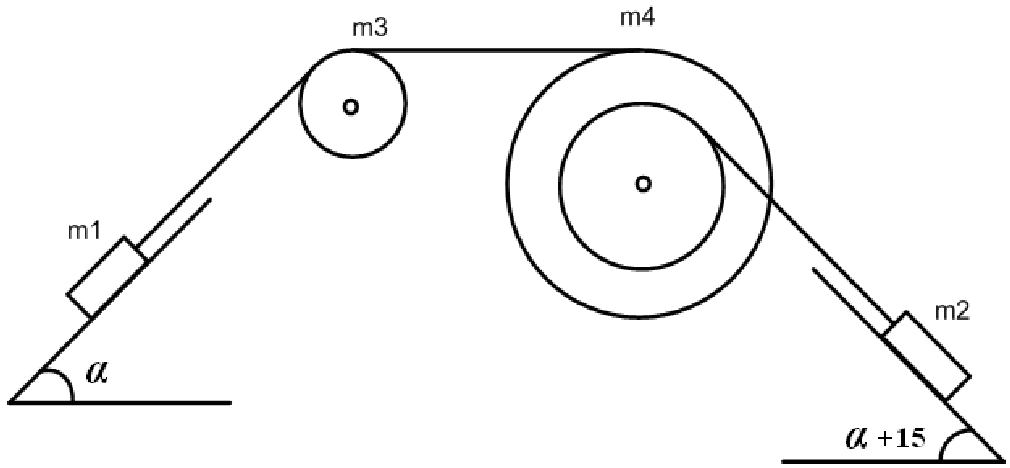


Figure 7.5

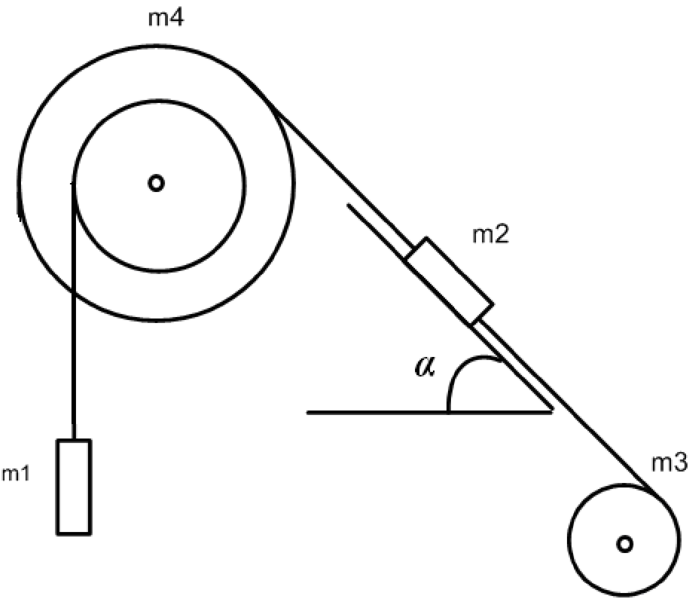


Figure 7.6

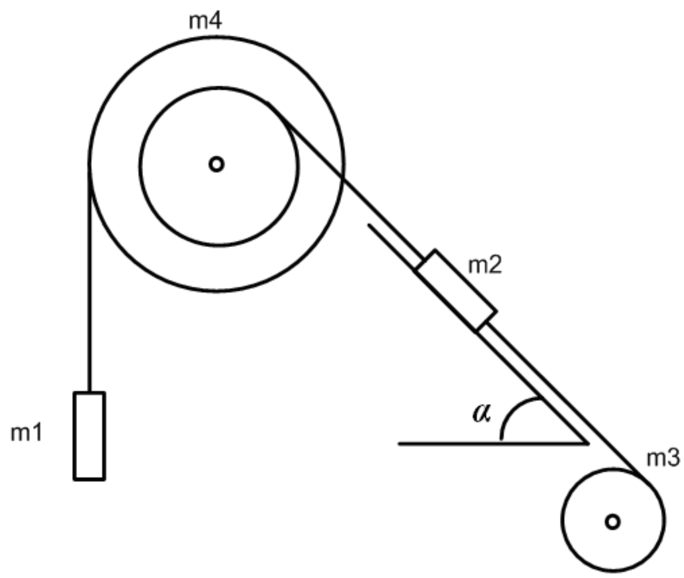


Figure 7.7

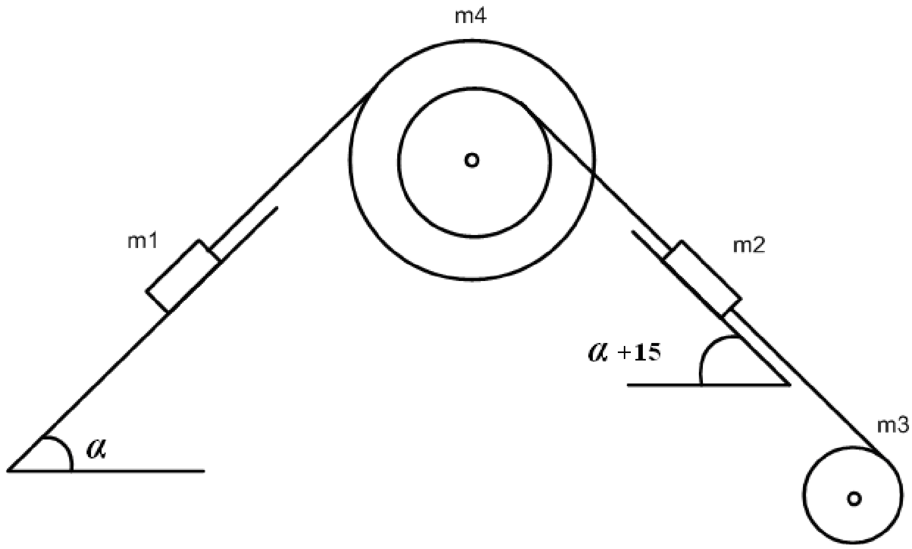


Figure 7.8

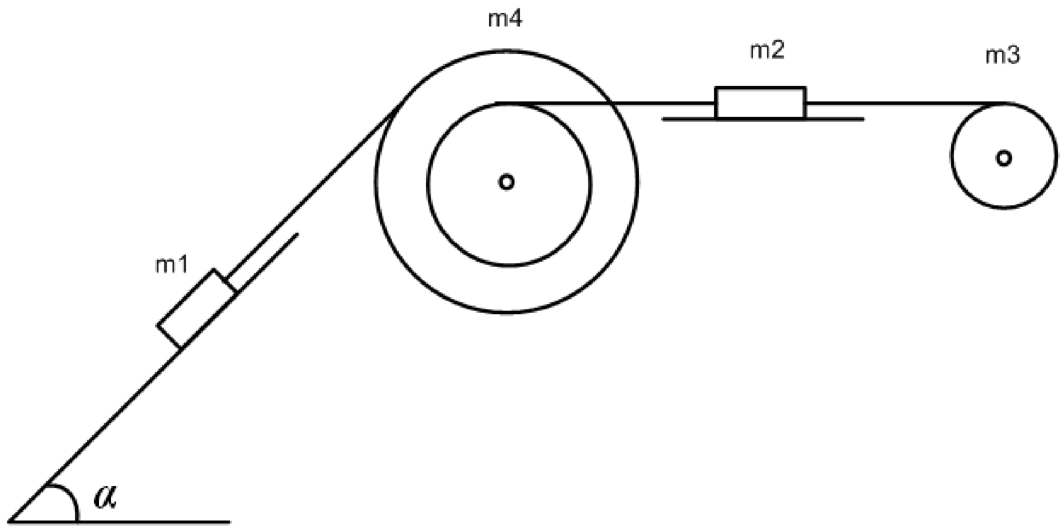


Figure 7.9

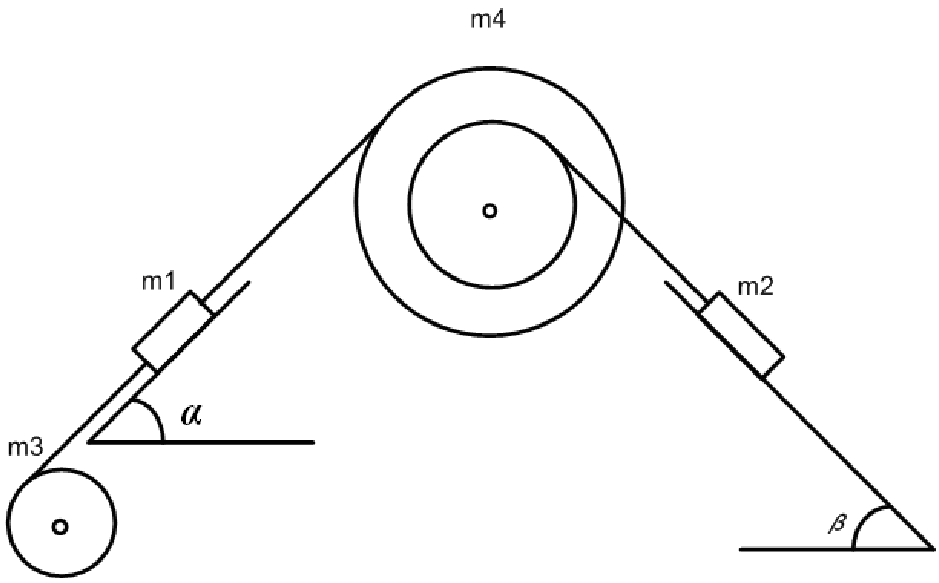


Figure 7.10

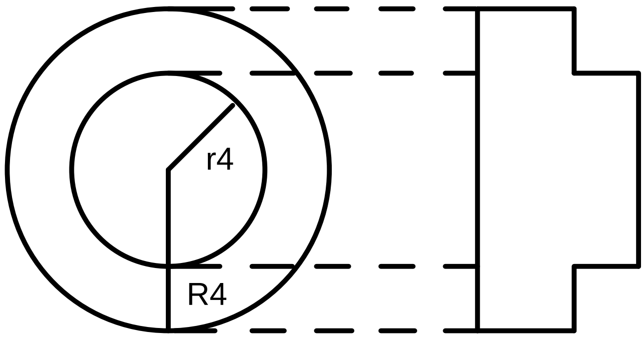


Figure 7.11

Problem № 8. Laws of Conservation. Oscillations.

Part 1

A system of bodies (a disk or a thin hoop with mass m_1 and radius R, long thin rods with masses m_2, a solid small ball with mass m_3) can pivot about a fixed axis. Axis goes through the point O perpendicular to the plane of the figure (see Figure 8.0–8.9).

1. Find the coordinates x_{cm} and y_{cm} of the center of mass.
2. Find the position vector r_{cm} of the center of mass.
3. Calculate the moment of inertia of the system I_s about the fixed axis.

A system of bodies is given as a part of an Atwood machine. Mass of the string and friction are negligible. Identify two appropriate times t_i and t_f for which data such as speed and initial position are known. If a mass Δm is added to one of the blocks with masses m (in the figure on the right), the system begins to move.

4. Use the data to establish an expression for total energy at times t_i and t_f.
5. Use the law of energy conservation and find the maximal angle between initial and final position of vector r_{cm}.
6. When the system is released from rest, find the final position of the blocks.

Part 2

The system of the bodies described in the previous exercise is at rest. Assume that this system is bumped by a plasticine ball of mass m_3. The initial velocity υ_0 (your own data) of the plasticine ball directed at angle θ with a vertical line. The plasticine ball sticks to the solid small ball with mass m_3 after the collision.

7. Find the resulting angular speed of the new system (the old system plus plasticine ball) after the collision.
8. Find the change in kinetic energy if the initial one is the energy of the plasticine ball before the collision, while final one is the energy of the system with the plasticine ball after the collision.
9. What is the maximum height by which the blocks of mass m rise after the collision of the plasticine ball with the system?

Part 3

A physical pendulum with rods and a small ball (see the data in Part 1) is pivoted about a point on its circumference as shown in Figure.

If we imagine the situation and say that the initial position of the pendulum is φ_{max}, we know the pendulum is undergoing simple harmonic oscillations. When the system is released from rest, find:

10. The total energy of the oscillating system.

11. The angular velocity and the angular acceleration of the object when its position is equal to one third of the maximum value.

12. State the equations in such a form that they are applied to a new pendulum and to another oscillating process (see Part 2), if the system is released not from rest.

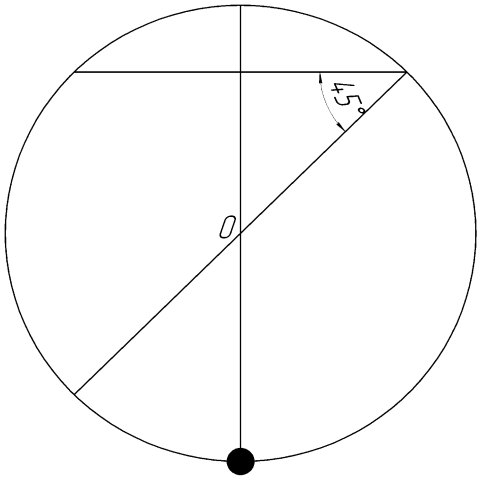


Figure 8.0

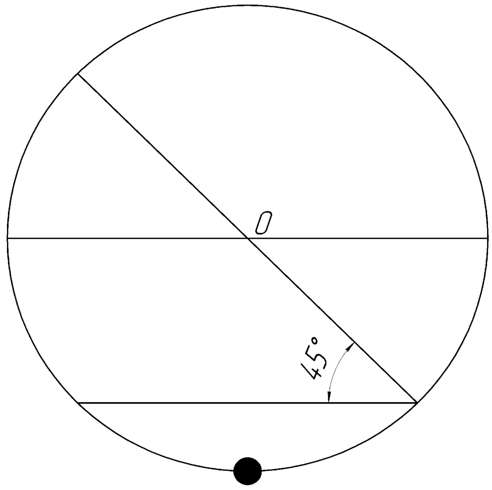
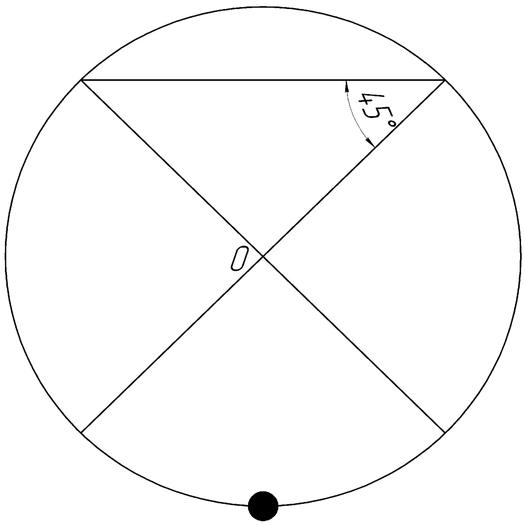


Figure 8.1



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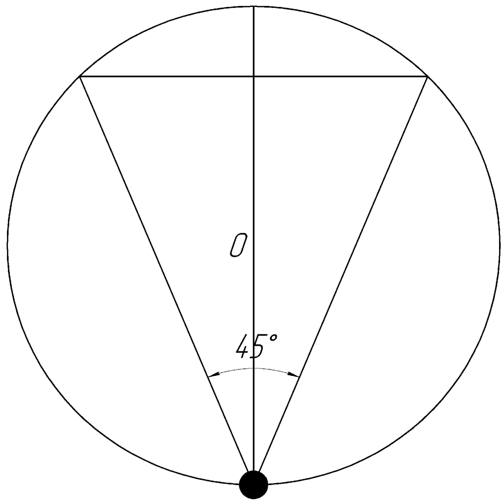
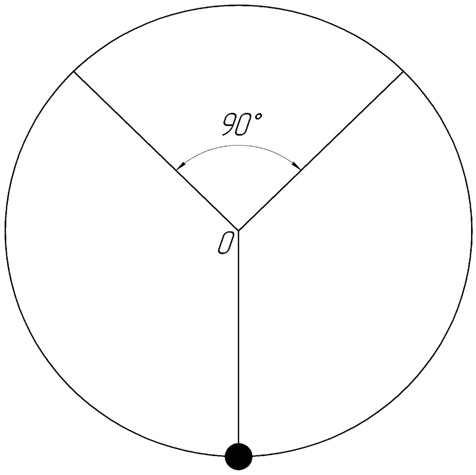


Figure 8.3



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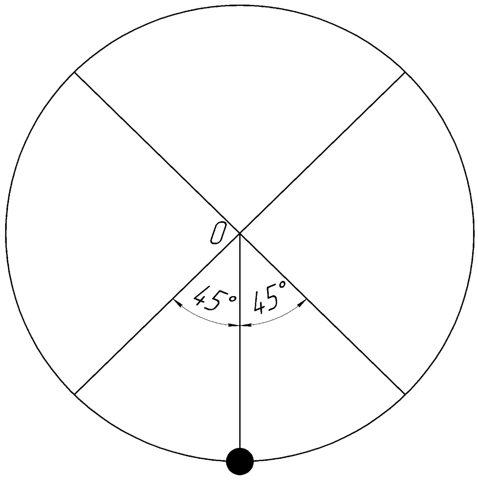
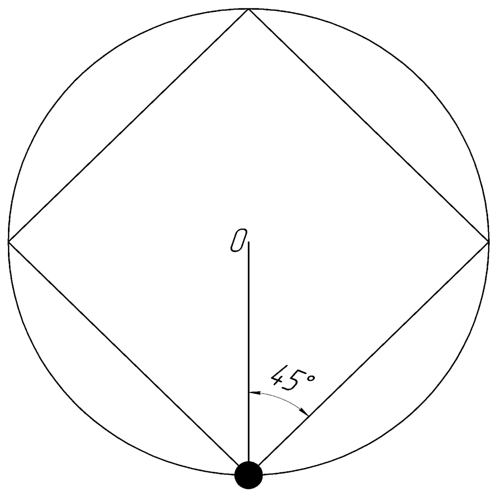


Figure 8.5



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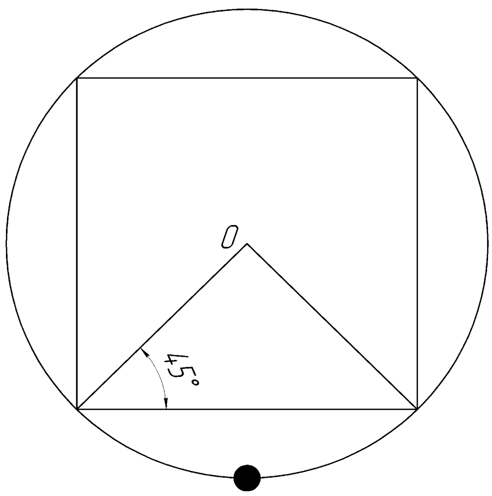

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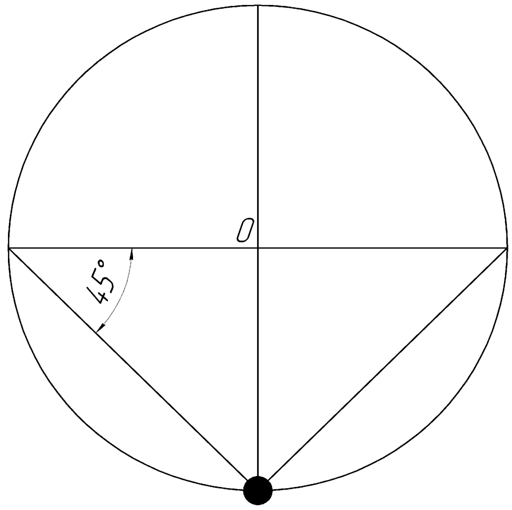


Figure 8.8

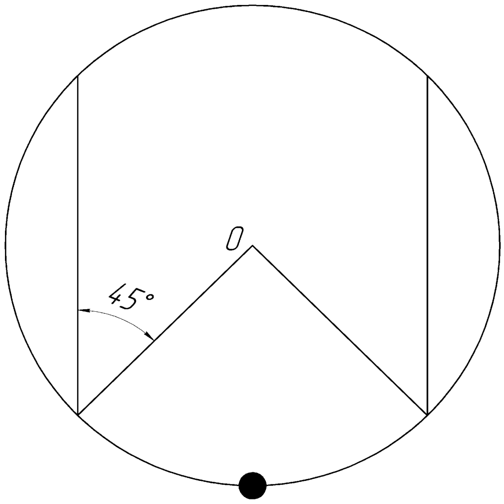


Figure 8.9

Data Table

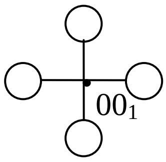
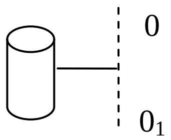
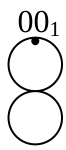
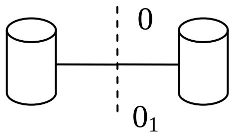
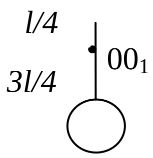
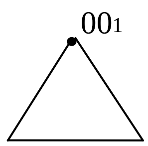
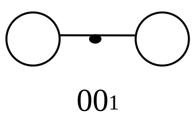
№	m_1, kg	R, m	m_2, kg	m_3, kg	α, deg	m, kg	Δm, kg	θ, deg
0	0.1	0.30	0.05	0.15	30	0.15	0.06	60
1	0.2	0.40	0.10	0.17	45	0.12	0.07	60
2	0.3	0.50	0.15	0.19	60	0.11	0.08	30
3	0.4	0.55	0.20	0.11	60	0.09	0.10	45
4	0.5	0.25	0.25	0.13	45	0.10	0.09	30
5	0.6	0.20	0.30	0.09	30	0.16	0.07	45
6	0.7	0.45	0.35	0.08	60	0.17	0.08	30
7	0.8	0.35	0.40	0.10	30	0.18	0.06	45
8	0.9	0.25	0.45	0.12	45	0.19	0.07	60
9	1.0	0.55	0.50	0.14	60	0.13	0.11	45

Problem № 9. Moment of Inertia. The Physical Pendulum.

A system of some bodies (a solid cylinder, a solid sphere, disks, hoops) of radius R and mass m_1, and thin rods with mass m_2 and length l can pivot about a fixed axis 00_1.

1. Find the coordinates x_{cm} and y_{cm} of the center of mass.
2. Find the position vector r_{cm} of the center of mass.
3. Calculate the moment of inertia of the system I_s about the fixed axis.
4. Determine the period T of small oscillation of your physical pendulum.
5. Find the reduced length L of your physical pendulum.

Data Table

№	m_1, g	R, cm	m_2, g	l, cm	System	Figure
1	100	4	150	20	Four balls and two thin rods	
2	200	4	150	20		
3	300	4	150	20		
4	400	4	150	20		
5	600	5	72	5	One solid cylinder and one thin rod	
6	600	5	72	10		
7	600	5	72	15		
8	600	5	72	20		
9	100	10			Two thin hoops	
10	100	20				
11	100	30				
12	100	40				
13	100	2	60	30	Two thin cylindrical shells and one thin rod	
14	200	2	60	30		
15	300	2	60	30		
16	400	2	60	30		
17	500	10	200	20	One disk and one thin rod	
18	500	10	200	40		
19	500	10	200	60		
20	500	10	200	80		
21			100	20	Three thin rods	
22			100	30		
23			100	40		
24			100	50		
25	150	4	120	10	Two disks and one thin rod	
26	150	6	120	10		
27	150	8	120	10		
28	150	10	120	10		

Problem № 10. Molecular Physics and Thermodynamics

An ideal gas (or a mixture of gases) undergoes the cycle as in the Figure.

1. Draw a pV-diagram for this cycle and show the cycle on a VT-diagram and pT-diagram. Label the points that represent states 1, 2, 3, and 4. Show the direction of the process. Characterize processes 1-2, 2-3, 3-4, 4-1.
2. Determine a pressure *p*, a volume *V*, a temperature *T* at all points of the cycle.
3. What is the work done by the gas, the change in the internal energy of the gas and the quantity of heat as a transfer of energy between the gas and its surroundings at processes 1-2, 2-3, 3-4, 4-1?
4. Calculate the efficiency of the heat engine, which operates in cycle 1-2-3-4-1.
5. Find the maximal T_{max} and minimal T_{min} temperatures in the cycle.

Note. The parameters given might not be enough to solve point 2. In this case, you can assign one parameter at any point of cycle 1-2-3-4-1 yourself.

Data Table

№	m_1, g	1st gas	m_2, g	2nd gas	p_1, kPa	p_2, kPa	V_1, L
0	8	He	4	H_2	500	300	30
1	40	Ar	48	O_2	450	250	25
2	40	Ne	42	N_2	400	150	20
3	84	Kr	70	Cl_2	350	200	35
4	131	Xe	8	H_2	300	100	40
5	88	CO_2	64	O_2	475	175	45
6	34	NH_3	28	N_2	600	275	50
7	54	H_2O	35	Cl_2	375	125	55
8	30	CH_3	6	H_2	550	350	60
9	52	C_2H_2	64	O_2	600	375	65

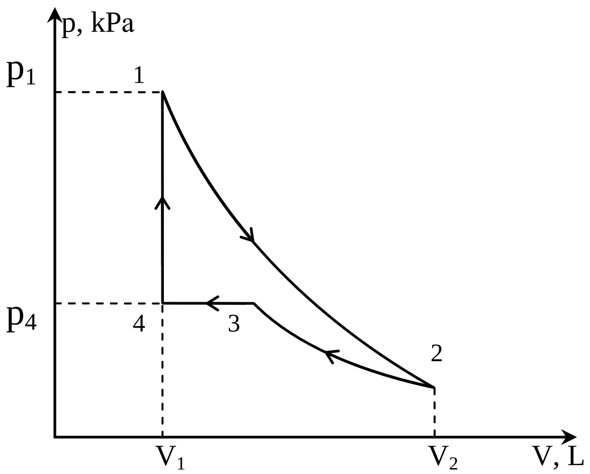


Figure 10.0

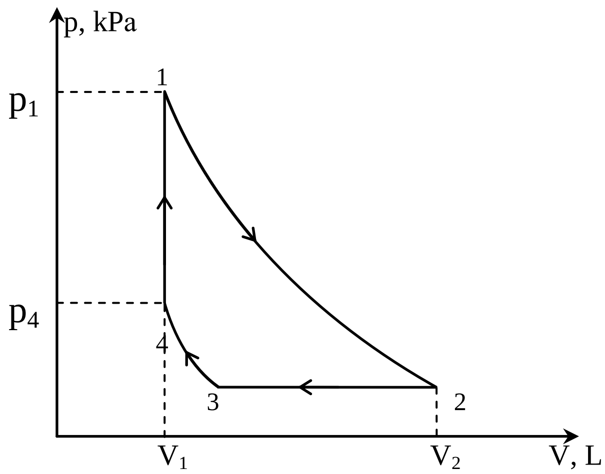


Figure 10.1

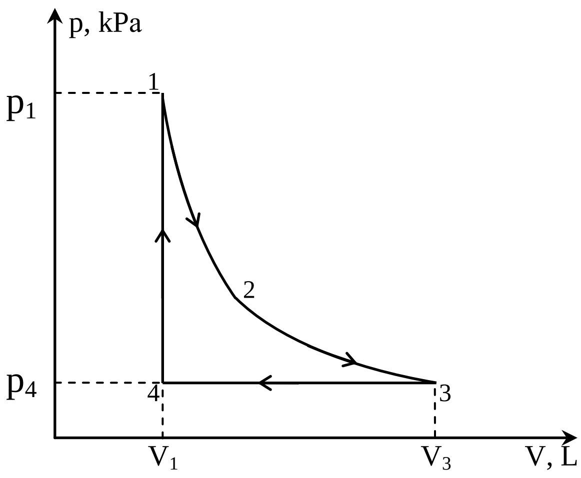


Figure 10.2

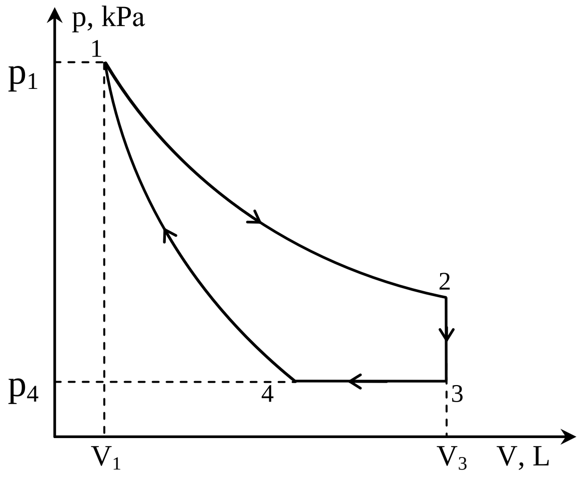


Figure 10.3

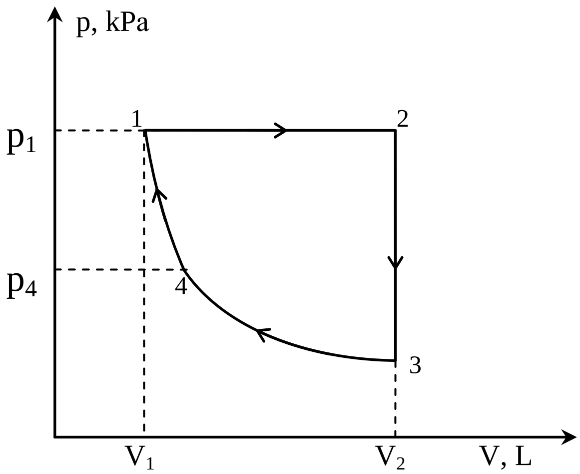


Figure 10.4

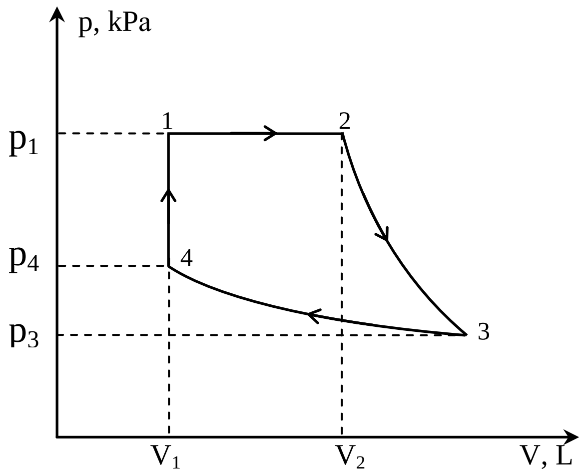


Figure 10.5

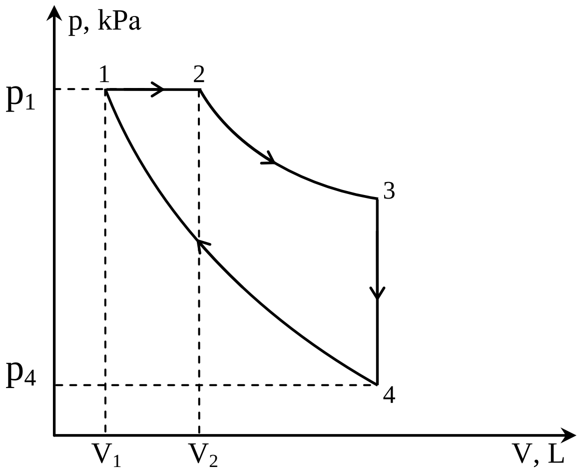


Figure 10.6

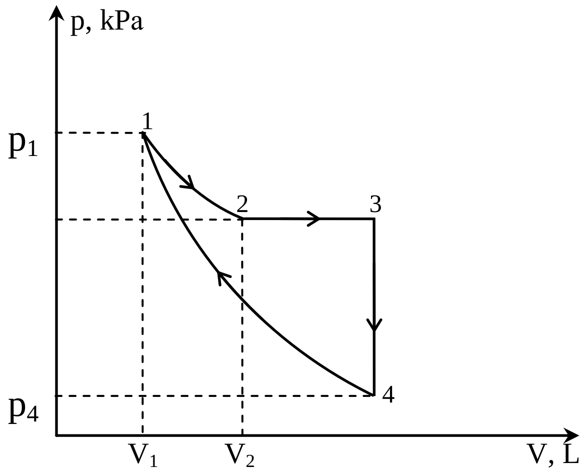


Figure 10.7

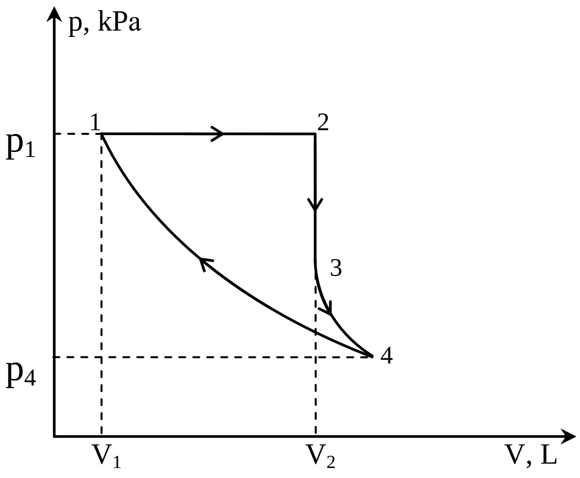


Figure 10.8

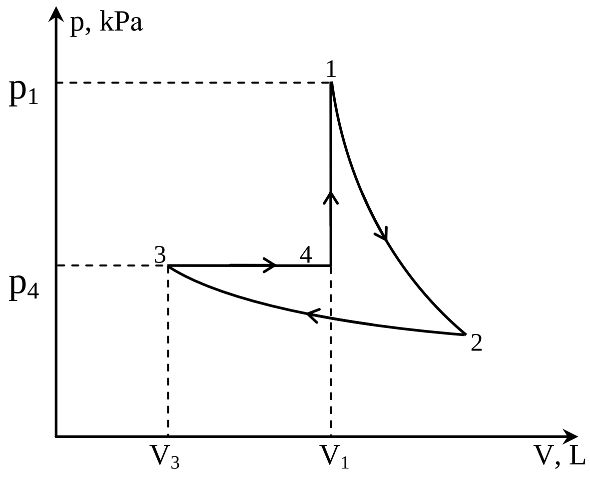


Figure 10.9

Problem № 11. Specific and Molar Heat Capacities. Calorimetry.

A gas with mass *m* and molar mass *M* has specific heat capacities at constant volume and at constant pressure c_v and c_p respectively. An important parameter for the gas is the ratio $\gamma = C_p/C_v$ where γ is an adiabatic constant. The number of degrees of freedom of the gas molecule is *i*.

Determine:

1. The unknown values.
2. The molar heat capacities at constant volume and at constant pressure C_v and C_p.

Calculate:

3. The change in internal energy of the gas for the temperature change ΔT.
4. How much heat must be added to the gas to raise its temperature by ΔT?
5. How much work the gas has done?

Data Table

№	c_v J/(kg·K)	c_p, J/(kg·K)	γ	*M*, 10^{-3} kg/mol	*I*	*m*, g	ΔT, K
1	?	?	1.667	4	?	8	5
2	?	1846.6	1.333	?	?	9	10
3	649.2	?	?	?	5	48	15
4	?	?	?	20	3	10	20
5	566.6	?	1.333	?	?	88	25
6	?	1846.6	?	18	?	27	30
7	?	1038.75	?	?	5	14	35
8	?	1038.75	1.667	?	?	40	40
9	148.74	247.9	?	?	?	42	45
10	10387.5	?	1.4	?	?	4	50
11	566.6	?	?	44	?	22	55
12	311.6	?	?	?	3	10	60
13	?	755.5	1.333	?	?	66	65
14	?	1038.75	?	28	?	7	70
15	?	1038.75	?	20	?	30	5
16	?	14542.5	?	?	5	10	10
17	?	?	1.4	32	?	48	15
18	3116.0	?	1.667	?	?	12	20
19	?	?	?	44	6	11	25
20	10387.5	?	?	?	5	8	30
21	?	?	1.333	18	?	36	35
22	?	908.9	1.4	?	?	16	40
23	566.6	?	?	?	6	22	45
24	?	?	?	40	3	20	50
25	742.0	1038.75	?	?	?	4	55
26	1385.0	?	?	?	6	6	60
27	?	?	?	2	5	6	65
28	?	5194.0	?	4	?	6	70

GLOSSARY

acceleration – ускорение
adiabatic process – адиабатический процесс
angle – угол
angular acceleration – угловое ускорение
angular speed – угловая скорость
average – средний
axis – ось
axle – ось, вал
ball – мяч, шарик
block – груз
circle – круг, окружность
circumference – окружность, круговой контур
collision – столкновение
conservation law – закон сохранения
cord – шнур, нить, стропа
curvature – кривизна, изгиб
cycle – цикл
equation – уравнение, равенство
exert – приложить силу
force – сила
free-body diagram – диаграмма свободного тела, силовая схема
friction – трение
harmonic – гармонический
heat capacity – теплоемкость
hoop – кольцо, обруч
inertia – инерция
instant – момент
instantaneous – мгновенный
internal energy – внутренняя энергия
isobaric process – изобарический процесс
isochoric process – изохорический процесс
isothermal process – изотермический процесс
linear – линейный
magnitude – величина, значение
mixture of gases – смесь газов
molar heat capacity – молярная теплоемкость
moment of inertia – момент инерции
number of degrees of freedom – число степеней свободы
origin – исходная точка, точка начала координат
oscillation – колебание
path – путь
path lang – длина траектории

pendulum – маятник
pivot – вертеться, вращаться вокруг оси
plasticine – пластичный
point of release – точка начала движения
pressure – давление
pulley – ролик, блок (механизм в форме колеса с жёлобом по окружности)
quantity heat – количество теплоты
radius-vector – радиус-вектор
reference frame – система координат
rest – состояние покоя
revolution – оборот
rod – прут, стержень
rotation – вращение, оборот
rotational motion – вращательное движение
simple – простой
solid – твёрдое тело, твердотельный
specific heat capacity – удельная теплоемкость
speed – модуль скорости
string – струна
tangential acceleration – тангенциальное ускорение, касательное ускорение
tension – растяжение, напряжение
torque – крутящий момент
translational motion – поступательное движение
unit vector – единичный вектор
value – значение, величина
velocity – вектор скорости
volume – объем
work – работа

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«Mechanics and Molecular Physics»

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