SOLVING NON-STANDARD PROBLEMS ON MECHANICS

[1]Tolipov F.M., [2]Abdukhalilova Oltinoy Shovkiddin Kizi, [3]Sobitova Mukhlisa Fazliddin kizi
[1]Doctor of Physics- athematical Sciences, Professor, Tashkent State Pedagogical University named after Nizami
[2,3] Students of Tashkent State Pedagogical University named after Nizami
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Abstract. *Examples of solving non-standard tasks from the section of mechanics are given. The course of the solution and the obtained numerical result are explained.*
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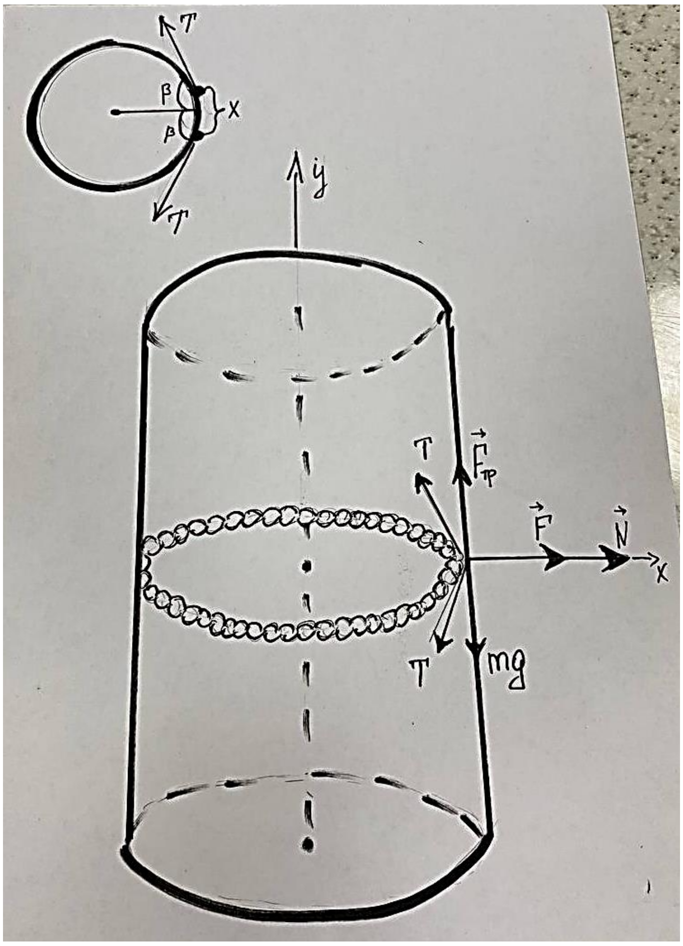
What is the degree of students' understanding of physical laws can be recognized by the ability to apply them to analyze specific physical phenomena, as well as to solve problems. The solution of physical problems is a necessary and extremely important step in the study of physics.

When solving non-standard problems in physics, a student is required to have ingenuity, deep knowledge, the ability to understand an unusual or complicated situation [2].

Task 1:

A closed chain with a mass (m) of 157 grams is put on with an "interference" (that is, tightly) on a rigid vertical cylinder with a radius (R) of 5 cm. The tension of the chain (T) is 3N. To what angular velocity (ω) must the cylinder be spun in order for the chain to slide down from it? The friction coefficient of the chain on the cylinder (μ) 0.1.

(Take π= 3.14, g=10 m/s²).



The basic equation of dynamics is Newton's second law - a vector equation [3]. In the problem under consideration, you can choose a coordinate system so that the vector equation of the second law is reduced to two scalar ones:

$$\vec{F}+\vec{T}+\vec{T}+\vec{N}+\overrightarrow{\Delta mg}+\overrightarrow{F_{\text{уб}}}=0 \qquad (1)$$

We write down the projections of forces on the OX axis:

$$\text{OX: } -2\text{T}\cdot cos\beta+\text{N}+F_{\text{уб}}=0 \qquad (2)$$

We write down the projections of forces on the OY axis:

$$\text{ОУ: } \mu\text{N}-\Delta\text{mg}=0 \qquad (3)$$

In relations (2) and (3) we find the reaction force of the support and the centrifugal force:

$$\text{N}=\frac{\Delta mg}{\mu} \qquad (4)$$

$$F_{\text{уб}}=2\text{T}\cdot cos\beta-\frac{\Delta mg}{\mu} \qquad (5)$$

We know that the centrifugal force is:

$$F_{\text{уб}}=\Delta\text{m}\omega^2\text{R}$$

Equate and equal parts of equations (4) and (5):

$$\Delta\text{m}\omega^2\text{R}=2\text{T}\ cos\beta-\frac{\Delta mg}{\mu}$$

From here we find the square of the cyclic frequency:

$$\omega^2=\frac{2\text{T}\ cos\beta}{\Delta\text{mR}}-\frac{g}{\mu R} \qquad (6)$$

The length of the circle is: $l=2\pi R$

$$\Delta\text{m}=\frac{x}{l}\text{m}=\frac{x}{2\pi R}\text{m}$$

Here Δm is the mass of one element of the chain, and x is the length.

The beta angle is:

$$\beta=\frac{\pi}{2}\ \frac{\frac{l}{x}-2}{\frac{l}{x}}=\frac{\pi}{2}-\frac{\pi x}{l}$$

We use the trigonometric transformation formula:

$$cos\beta=\cos\left(\frac{\pi}{2}-\frac{\pi x}{l}\right)=\sin\frac{\pi x}{l}$$

$$cos\beta=\sin\frac{\pi x}{2\pi R}=\sin\frac{x}{2R}$$

In place of Δm and cosine betta, we substitute their values in equation (6). As a result, we obtain the value of the cyclic frequency:

$$\omega^2=\frac{2T\cdot sin\frac{x}{2R}}{\frac{xx}{2\pi R}\cdot R}-\frac{g}{\mu R}=\frac{2T\cdot sin\frac{x}{2R}}{\frac{mR}{\pi}\cdot\frac{x}{2R}}-\frac{g}{\mu R}=\frac{2\pi T}{mR}-\frac{g}{\mu R}$$

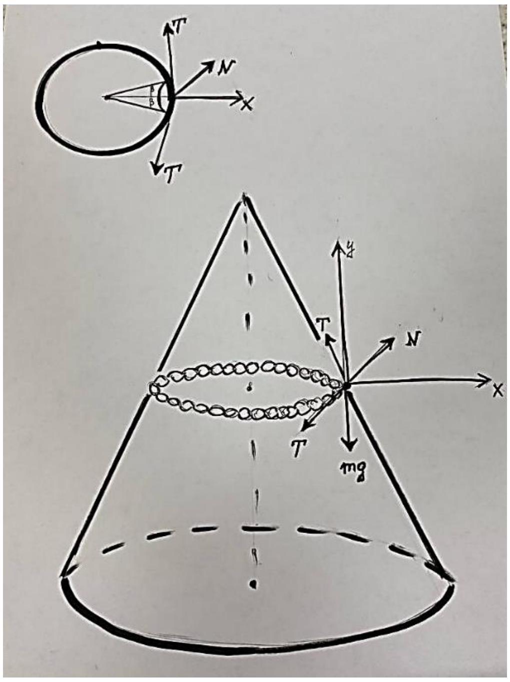
$$\omega^2=\frac{2\cdot 3{,}14\cdot 3}{0{,}157\cdot 0{,}05}-\frac{10}{0{,}1\cdot 0{,}05}=2400\cdot 200=400$$

$$\omega=20\ \text{rad/s}$$

Answer: w=20 rad/ s.

Task 2:

A chain with a length (l) of 1 m and a mass (m) of 157 g was closed into a ring and put on top of a smooth circular cone with a vertical axis and a semi-opening angle (α) of 45 °. What will be the tension (T) (in mH) of the chain if the cone put into rotation so that each element of the chain has a speed (v) of 2 m/s? (Take π=3,14 ,g=10 m/s²).



The solution of this dynamic task should begin with an analysis of all the forces acting on the chain element. The forces acting on the chain element are shown in Figure 2. Based on Newton's second law, in this case we have:

We summarize the forces depending on their direction.

$$\overrightarrow{\Delta mg}+\vec{T}+\vec{T}+\vec{N}+\overrightarrow{m\vec{a}}=0 \qquad (1)$$

To study the relation (1) projected on the axis OX and OУ:

$$\text{OX: } -2T\cdot cos\beta+N\cdot\cos\alpha+\frac{\Delta m v^2}{r}=0 \qquad (2)$$

$$\text{OУ: } -\Delta mg+N+\sin\alpha=0 \qquad (3)$$

From equations (2) and (3) we find the centrifugal force:

$$2T\cos\beta+N+\cos\alpha+\frac{\Delta m v^2}{R}=0$$

$$\frac{\Delta m v^2}{R}=2T\cos\beta-N\cos\beta$$

Where Δm here is the mass of one link of the chain, and x is the length:

$$\Delta m=m\frac{x}{l} \qquad (4)$$

$$\Delta mg=N\sin\alpha$$

$$\Delta mg=N\cos\beta$$

since $\sin\alpha=\cos\beta$ taking $\alpha=45°$, then

$$\frac{\Delta m v^2}{R}=2T\cos\beta-\Delta mg \qquad (5)$$

Let's write the relationship between the angles.

Angle β - smallest angle <90°

Figure 2 shows that the sum of the alpha and beta angles is 90°.

$$\alpha+\beta=\frac{\pi}{2}$$

The length of the circle is

$$l=2\pi R$$

First, we determine the angle betta, and then we convert its cosine to a sine.

$$\beta = \frac{\pi}{2}\cdot\frac{\left(\frac{l}{x}-2\right)}{\frac{l}{x}} = \frac{x}{2l}\,\pi\left(\frac{l}{x}-2\right) = \frac{\pi}{2}-\frac{\pi x}{l}$$

$$\cos\beta=\cos\left(\frac{\pi}{2}-\frac{\pi x}{l}\right)\cdot\left(\frac{\pi}{2}-\frac{\pi x}{l}\right) = sin\frac{\pi x}{l}$$

Instead of R, we put its value from (6) into the equation (5) :

$$\frac{\Delta m v^2}{\frac{l}{2\pi}} = 2T\sin\frac{\pi x}{l} - \Delta mg$$

$$\frac{2\pi\cdot\Delta m v^2}{l} = 2T\sin\frac{\pi x}{l} - \Delta mg$$

Let's use the equation (4) :

$$\frac{2\Delta m v^2}{l} = 2T\frac{\sin\frac{\pi x}{l}}{\frac{\pi x}{l}} - \frac{mg}{\pi} \qquad (7)$$

From the Remarkable Limits Theorem, we have:

$$\lim_{x\to 0}\frac{sin\frac{\pi x}{l}}{\frac{\pi x}{l}} = 1$$

Plug this into the equation (7):

$$2T\cdot\frac{sin\frac{\pi x}{l}}{\frac{\pi x}{l}} = 2\,\frac{mv^2}{l} + \frac{mg}{\pi}$$

From here we find the tension force:

$$T=\frac{mv^2}{l}+\frac{mg}{2\pi}$$

$$T=\frac{mv^2}{l}+\frac{mg}{2\pi}=\frac{0,157\cdot 4}{1}+\frac{0,15\cdot 10}{2\cdot 3,14}=0,878=878\mu H$$

Answer: T= 878 мН

Thus, the problems considered are of interest, despite their original nature, as they help to better understand the dynamics of movement along a circle in the case of two projections.

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