SOLUTION OF QUANTITATIVE PROBLEMS ON THE SECTION OF PHYSICS "MECHANICS"

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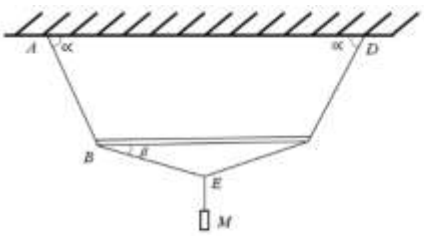
ABSTRACT. *This article provides examples of methods for solving problems in the section of physics "Mechanics". It has been shown that other problems can be solved using each problem solving method. Before solving physical problems, opinions were expressed about the importance of analyzing drawings on the subject by logical reasoning.*

Keywords: mass, rod, tensile force, gravityforce, free fall, acceleration, reaction force, height, force, equilibrium, position, kinetic energy, potential energy,

Task 1. A homogeneous rod of mass *m* = 6 kg is suspended on a rope, as shown in fig. 1. The mass of the load on which the rod is suspended is *m* = 10 kg. Determine the tension force *T* on the thread and the reaction force *F* on the rod.



Given:

m=6 kg

M= 10 kg

Need to find:

T=? F=?

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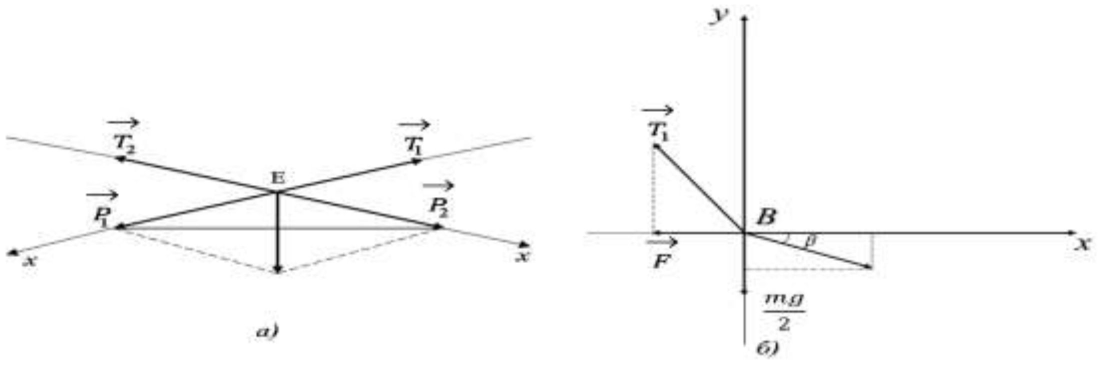


Figure 1

*Solution.*The forces acting on point *E* are as follows: force *P* - *m* is the gravity of the body and T_2 is the tensile force (Fig. 2-*a*). We will divide the force *P=mg* into components in the directions *x*. In this case $P=T_2$ or

$$\frac{\frac{P}{2}}{P_2} = \frac{\frac{P}{2}}{T_2} = \sin\beta,$$

from this

$T_2=\frac{Mg}{2\sin\beta}$,that's$T_2= T_{BE} = T_{EC} = \frac{Mg}{2\sin\beta}$.

Now let's show the forces acting on point *B* (Fig. 2-*b*): T_2 - tension force, T_1 - tension force, *F* - rod reaction force, consists of gravity force.

Figure 2

Let us describe these forces in the diagram and divide them into horizontal and vertical components in two directions. Since point *B* is motioless, the sum of the projections of forces in any direction must be zero. So in the vertical direction:

$$T_1 \sin \propto = T_2 \sin\beta + \frac{mg}{2}$$

or

$T_1 \sin \propto = \frac{Mg}{2} + \frac{mg}{2}$,

from this

$T_1 = \frac{(M+m)g}{2\sin\propto}$ or $T_1 = T_{AB} = T_{DC} = \frac{(M+m)g}{2\sin\propto}$

Figure 2.

In the same horizontal direction:

$F + T_1 \cos \propto = T_2 \cos \beta$,

from this

$F = T_2 \cos\beta - T_1 \cos \propto = \frac{Mg}{2} ctg\beta - \frac{(M+m)g}{2\sin\propto} ctg \propto = \frac{g}{2}[Mctg\beta - (M-m)ctg \propto]$.

Answer: $T_2 = \frac{Mg}{2\sin\beta}$; $T_1 = \frac{(M+m)g}{2\sin\propto}$; $F = \frac{g}{2}[Mctg\beta - (M-m)ctg \propto]$.

Task 2. Determine the tension *T* of the thread associated with a ball of mass *m* and the compression force *N* on the inclined plane of the ball (Fig. 3). The angle of inclination of the inclined plane is equal to the angle between the thread and the vertical. The friction between the ball and the plane is ignored.

Given:

$m; \propto; \beta$.

Need to find:

T=? N=?

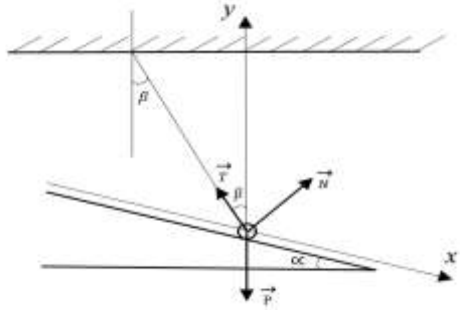


Figure 3

Solution: Based on the principle of the presence of interaction and force, we determine the forces acting on the ball. These forces are the force of gravity *P*, acting due to the interaction of the ball with the Earth, the tension force *T* between the ball and the thread, is the reaction force *N* of the inclined plane. These forces are shown in the figure (Fig. 3).

Let us determine the directions of separation of forces into components, one of which is directed vertically, the other in an inclined plane. We find the projections of these forces on the chosen directions and then write down the equilibrium condition, i.e. the ball is in a state of motionless under the action of these forces:

$T\cos\propto + N\cos\beta = P$ – in the vertical direction.

$P\sin\propto = T\cos[90-(\propto+\beta)] = T\sin\propto(\propto+\beta)$ –on an inclined plane.

From the second equation we find *T*:

T = .

We put this value of *T* into the first equation, in this case:

$$\frac{mg\sin\propto\cos\beta}{\sin(\propto+\beta)} - mg = -N\cos\propto$$

or

$$N\cos\propto = mg - \frac{mg\sin\propto\cos\beta}{\sin(\propto+\beta)}$$

from this

N = - = ( )= () =

$$\frac{mg\cos\propto\sin\beta}{\cos\propto\sin(\propto+\beta)} = \frac{mg\sin\beta}{\sin(\propto+\beta)}.$$

Answer: $T = \frac{mg\sin\propto}{\sin(\propto+\beta)}$; $N = \frac{mg\sin\beta}{\sin(\propto+\beta)}$;

Task 3. An elastic thread stretched over the walls of an elevator oscillates under the action of a load suspended in the middle, as shown in fig. 4. Oscillation angle $\propto_1=30^\circ$ in a motionless elevator and $\propto_2=45^\circ$in a moving elevator with acceleration. Determine the magnitude and direction of acceleration *a* of the elevator. Ignore the weight of the rope.

Given:

α_1=30˚;

α_2=45˚.

Need to find: *a* = ?

Figure 4

Solution: Consider the position of point *A* for a motionless elevator. It is acted upon by gravity force *P* and tension forces. These forces are shown in the figure (Fig. 4). We divide the force *P* into components in the directions of the thread. Tension force

$T = P_1 = \frac{P}{2 sin\alpha_1}$,

where is the angle of inclination of the thread when the elevator is motionless. Let the length of the thread be *l*, then half of it

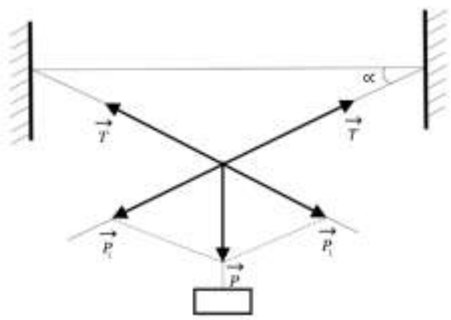
$\frac{\frac{l}{2}}{OA} = \cos\alpha_1$ ёки $OA = \frac{l}{2\cos\alpha_1}$,

$$\Delta l = OA - \frac{l}{2} = \frac{l}{2\cos\alpha_1} - \frac{l}{2} = \frac{l}{2}(\frac{1}{\cos\alpha_1} - 1) = \frac{l}{2}(\frac{1-\cos\alpha_1}{\cos\alpha_1}).$$

The magnitude of the straining force at the elastic limit is proportional (Hooke law):

T = *kl;* = *k*().

where *l* is the absolute elongation of the thread. When the elevator moves with acceleration *a*:



$$T_1 = k\Delta l; \quad \frac{P}{2\sin\alpha_1} = k\frac{1}{2}(\frac{1-\cos\alpha_2}{\cos\alpha_2}).$$

In this case, according to Newton's second law, it is necessary to take into account the force *F=mg+ma*, *a* is the solution of the system. The equilibrium condition for an object is $P—F_A = P_{1'}$ where F_A - is the buoyancy force.

This expression can be written as:

$P\text{-}V_{P1g}=P_{1'}$

In this case, the volume of the body V can be written as follows for a second fluid of the same size:

$P\text{-}V_{P2}\,g= P_2$

where

$P - P_2 = Vp_2 g$ or $_{P2} = \frac{P-P_2}{Vg}$.

From the first equation we find:

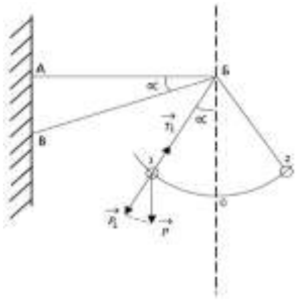
$P - P_1 = Vp_1 g$; $V= \frac{P=P_1}{p1g}$

We substitute this value V into the expression $_{p1}$:

$_{P2} = \frac{(P-P2)p1g}{(P-P1)g} = \frac{(P-P2\ p1}{P-P1}.$

Answer: $_{P1}=\frac{(P-P2)p1}{P-P1}.$

Task 4. A ball of mass m=100 g is suspended on a bracket with a thread of length ($\alpha = 30^0$)*l* = 1м(Fig. 5). A ball in equilibrium was given a horizontal velocity v = 2 m/s, after which it began to oscillate. Determine the forces acting on the rods AB and БВ when the ball is at points as far as possible from the equilibrium position.



Given:

$\alpha = 30^0$;

m=100 g;

v =2 m/s;

l = 1 m.

Need to find:

$T_{АБ}$=? $T_{ВБ}$=?

Figure 5

*Solution.*The ball has kinetic energy in case 0 and so on in case *l*

$\frac{mv^2}{2}$=mghor h =$\frac{v^2}{2g}$.

So

l = h = l -$\frac{v^2}{2g}$; cos $\gamma = \frac{l-h}{l}$

orcos γ = (1- $\frac{v^2}{2g}$)

We project the force P onto the direction of the force T_1, then

$P_1 = P \cos \gamma$,

from this

$T_1 = P_1 = mg\,(1-\frac{v^2}{2gl})$.

Forces T_1, $T_{ВБ}$and$T_{АБ}$, act on point *Б*, the direction of which is shown in Figure 6. We divide the forces into horizontal and vertical components, while the equilibrium condition for point *Б* in the vertical direction has the form:

$T_1 \cos \gamma = T_{ВБ} \sin\alpha$,

from this

$T_{ВБ} == \frac{T_1 \cos\gamma}{\sin\alpha} = \frac{mg\,(1-\frac{v^2}{2gl})}{\sin\alpha}$.

In the horizontal direction:

$T_1 \sin \gamma = T_{АБ} + T_{ВБ} \cos\alpha$,

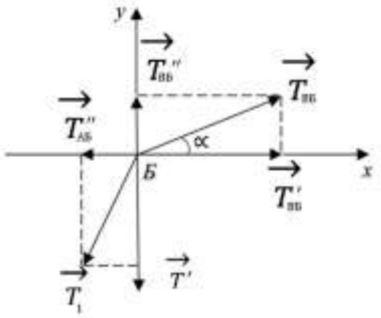
or

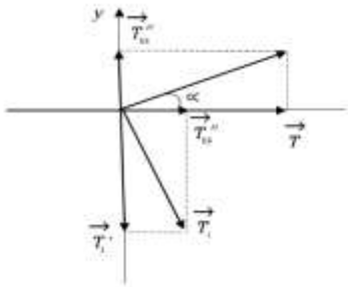
$mg \cos\gamma \sin\gamma = T_{АБ} + \frac{mg\cos^2\gamma\cos\alpha}{\sin\alpha}$,

from this

$$T_{AБ} = \frac{mg(cos\gamma sin\gamma \sin\alpha - cos^2\gamma\cos\alpha)}{\sin\alpha},$$

or $$T_{AБ} = \frac{mgcos\gamma(sin\gamma sin\alpha - cos\gamma cos\alpha)}{\sin\alpha}.$$





$$T_{AБ} = -\frac{mgcos\gamma(cos\gamma cos\alpha - \sin\gamma sin\alpha)}{\sin\alpha} = -\frac{mgcos\gamma cos(\alpha+\gamma)}{\sin\alpha}.$$

Figure 6. Figure 7.

The minus sign indicates that $T_{AБ}$ force is directed in the opposite direction of the graph.

In the second case, the scheme of forces acting on point *Б* changes significantly. Taking this into account and the instructions in the first part of the solution, we build a new diagram (Fig. 7). In this case:

$T_{BБ}\sin\alpha = T_1\cos\gamma$ – vertically, from this

$$T_{BБ} = \frac{T_1\cos\gamma}{\sin\alpha} = \frac{mg\,cos^2\gamma}{\sin\alpha}.$$

$T_{AБ} = T_1\sin\gamma + T_{BБ}\cos\alpha$ – horizontally, from this

$$T_{BБ} = mg\left(\frac{cos^2\gamma\cos\alpha}{\sin\alpha} + \cos\gamma\sin\gamma\right).$$

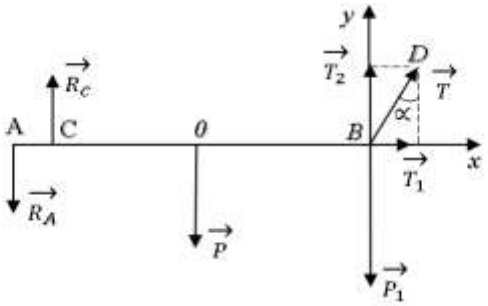
To the right of the equation, we make trigonometric changes, that is, we add and subtract to it and create a strong identity equal to the first:

$T_{AБ}$ = mg ($\frac{cos^2\gamma cos\alpha}{\sin\alpha}$ + $\cos\gamma\sin\gamma + \cos\gamma\sin\gamma - \cos\gamma\sin\gamma$)= mg ($\frac{cos^2\gamma cos\alpha}{\sin\alpha}$ - $\cos\gamma\sin\gamma + 2\cos\gamma\sin\gamma$) = mg ($\frac{cos^2\gamma cos\alpha - cos\gamma sin\gamma sin\alpha}{\sin\alpha}$$+\sin2\gamma$) = mg ($\frac{\cos\gamma\cos(\alpha+\gamma)}{\sin\alpha}$ $+\sin2\gamma$).

Now let's calculate the desired value:

$\cos\gamma$ = $(1-\frac{v^2}{2gl}) \cong$ 0,8.

$\sin\gamma = \sqrt{1 - cos^2\gamma}$ = 0,6.



here

γ = arccos0,8 = $36^\circ 56'$, $\cos(\alpha + \beta)$ = cos $86^\circ 56'$.

a) T_1 = 0,7 H; $T_{AБ}$ = 0,6 H; $T_{BБ}$ = 1,25 H;

b) T_1 = 0,7 H; $T_{BБ}$ = 1,25 H; $T_{AБ}$ = 1,54 H;

Answer:

a) $T_1 = mg$ cosγ; $T_{BБ} = \frac{mgcos^2\gamma}{\sin\alpha}$; $T_{AБ} = \frac{mg(cos\gamma\cos(\alpha+\gamma)}{\sin\alpha}$

б) $T_1 = mg$ cosγ; $T_{BБ} = \frac{mgcos^2\gamma}{\sin\alpha}$; $T_{AБ}$ = $(\frac{cos\gamma\cos(\alpha+\gamma)}{\sin\alpha} + \sin2\gamma)$.

Task 5. Beam *AБ* is fixed as shown in Figure 8. A load of mass *M* = 15 kg is suspended at point *B*. Determine the reaction force at points *A* and *C* and the tensile force of the thread *BD*. Beam mass is*m*=5 kg, *AC*=*a*=0.25, *AB*=*b*=1 m,$\alpha = 60^\circ$.

Given:

M = 15 kg;

m = 5 kg;

AC = *a* = 0.25 m;

AB = *b* = 1 *m*;

Need to find:

R_A= ? $\overrightarrow{R_A}$ R_C= ? T= ? Figure 8

Solution. A reaction force is a force that acts on an object and prevents it from moving in one direction or another, and active forces are all forces that are not related reaction forces. When solving problems of this type, it is necessary to follow a clear plan: first, identify all the forces acting on the beam; to write the equilibrium condition for these forces, it is necessary to take the projections of all forces acting on a material point (body) on the x and y axes and make their sum equal to zero: $\sum F_x = 0$ ва $\sum F_y = 0$. The reaction force at point C is equal in magnitude to the reaction force at point A (vertically), i.e. balance is maintained horizontally. Therefore, we do not take into account forces in the horizontal direction.

If we determine the distance to the mass $2m$, then

$$B_1K_1 = \frac{a\sqrt{3}}{2} - \frac{3a\sqrt{3}}{16} = \frac{8a\sqrt{3} - 3a\sqrt{3}}{16} = \frac{5a\sqrt{3}}{16}.$$

The second way to solve the second part of the problem. The center of gravity of each side of the triangle is in its middle, and the center of gravity of the triangle is at the point of intersection of its heights, i.e. an equal acting force equal to $12mg = R$ point is applied to this (Fig. 9).

$$\overrightarrow{\mathrm{P}} = 2mg \qquad \overrightarrow{P_2} = mg \quad and \ \overrightarrow{P_2} = mg$$

and the same action of forces atpoint $\frac{LE}{2} = \frac{\sqrt{3}}{4}$ is equal to

$R_1 = 4mg$.

Here the distance OO_1:

$$OO_1 = \frac{a\sqrt{3}}{4} - \frac{a\sqrt{3}}{6} = \frac{3a\sqrt{3} - 2a\sqrt{3}}{12} = \frac{a\sqrt{3}}{12}.$$

Now let's move on to solving the problem: we need to find the base point of the lever in Figure 10, which is in equilibrium. Let this point be K. Then $OK = x$, we obtain the equilibrium condition for the lever:

$x \cdot 12mg = \left(\frac{a\sqrt{3}}{22} - x\right) \cdot 4mg,$

$3x = \frac{a\sqrt{3}}{12} - x,$ $\quad 4x - \frac{a\sqrt{3}}{12},$ $\quad x = \frac{a\sqrt{3}}{48},$

in this case

$LK = \frac{a\sqrt{3}}{2} - \frac{3a\sqrt{3}}{16} = \frac{8a\sqrt{3} - 3a\sqrt{3}}{16} = \frac{5a\sqrt{3}}{16}.$

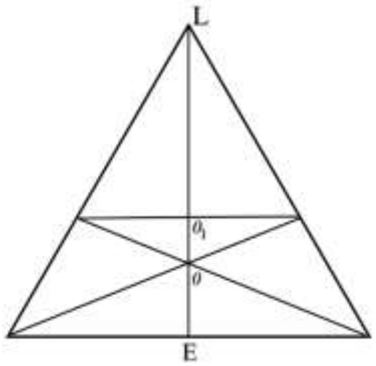


Figure 9.

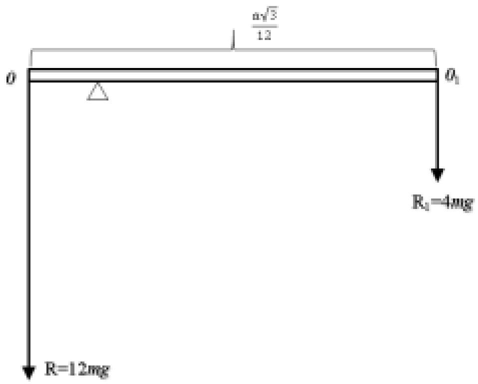


Figure 10.

Answer: $\quad CK = \frac{a\sqrt{3}}{4},$ $\quad LK = \frac{5a\sqrt{3}}{16}.$

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