

Technique For Solving Problems in Mechanic

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Abstract:

This article discusses examples of problems to be solved in the mechanics department of the physics course and methods of their solution. Here are some ways to solve each problem in several ways.

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Introduction

In the macroscopic world around us, all the variety of forces encountered, except for gravitational forces, is a manifestation of electromagnetic interactions. When studying the laws of mechanics that describe the motion of bodies, we met with elastic forces that allow solids to maintain their shape and size and reveal themselves when they are deformed. The forces of elasticity prevent the change in the volume of liquids and the compression of gases. We have also met with friction forces, the manifestations of which in the world around us are extremely diverse and by no means can be reduced only to the deceleration of the movement of solids, liquids and gases. When studying the subject of physics, the mastering of the section of mechanics has a very important role.

Materials and Methods

Connection of the discipline "Physics" with technology and other natural sciences and their importance in the development of these sciences. General information about mechanics. Coordinate system. Space and geometry. Expression of vector quantities by their coordinates. Change of projections of coordinates and vectors. On the meaning of products and integrals in applications of physical problems. Elements of kinematics. Physical models: material point (particle or corpuscular), system of material points, absolute rigid body, continuous medium. The concept of matter, field and physical vacuum [1-5]. The movement of a point along a circle. Vectors of angular velocity and acceleration. Curved speed and acceleration.

Normal, tangential and full acceleration. The relationship between the kinematic characteristics of rotational and translational motion. Problem solving is an integral part of the general physics course. For mastering the above topics on mechanics, both theoretical and problem solving are of equal importance.

Let's show some examples of solving problems in the mechanics section.

Problem 1. A body located at a height H above the Earth was thrown horizontally with an initial velocity v_0 . Find the law of motion of the body, the equation of the trajectory, the laws of change in velocity and acceleration, as well as the normal and tangential projections of the acceleration and the radius of curvature of the trajectory at an arbitrary moment in time.

Solution I. Let us draw a drawing and depict on it the body velocity v_0 given in the problem statement at the initial time ($t = 0$) and the assumed trajectory of the body movement (Fig. 1). Let's choose a frame of reference related to the Earth. The X-axis of the Cartesian coordinate system is directed horizontally along the Earth's surface in the direction of the initial velocity v_0 , and the Y-axis is directed vertically upward to the position of the body at the initial moment of time.

We will assume that the body is a material point, and the movement of the body at the surface of the Earth occurs with a constant acceleration of gravity g .

II. In accordance with the selected frame of reference and the selected models of the body and its motion, we write down the initial conditions and the law of change in the acceleration of the body in projections on the coordinate axes:

$$\begin{cases} x(0) = 0, y(0) = H, \\ v_x(0) = v_0, v_y(0) = 0; \end{cases} \quad (1)$$

$$\begin{cases} a_x = \frac{dv_x}{dt} = 0, \\ a_y = \frac{dv_y}{dt} = -g. \end{cases} \quad (2)$$

III. The written differential equations for the projections of the velocity of a material point, taking into account the initial values, make it possible to find the law of change in the velocity of the body $v(t)$ and the law of its motion $r(t)$ in projections on the coordinate axes:

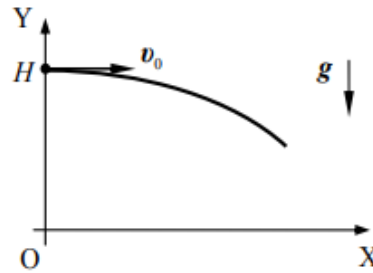
$$\begin{cases} v_x = v_0, \\ v_y = -gt; \end{cases} \quad (3)$$

$$\begin{cases} x = v_0 t, \\ y = H - \frac{gt^2}{2}. \end{cases} \quad (4)$$

The trajectory equation is found from the law of motion of the body in coordinate form (4) by eliminating the time t :

$$y(x) = H - \frac{gx^2}{2v_0^2} \quad (5)$$

The rest of the required quantities are determined in accordance with the formulas.



Speed module:

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{v_0^2 + (gt)^2}. \quad (6)$$

Acceleration module:

$$a = \sqrt{a_x^2 + a_y^2} = g. \quad (7)$$

Acceleration projections on the direction of velocity and the direction perpendicular to it are equal to:

$$a_\tau = \frac{dv}{dt} = \frac{g^2 t}{\sqrt{v_0^2 + g^2 t^2}}, \quad a_n = \sqrt{a^2 - a_\tau^2} = \frac{v_0 g}{\sqrt{v_0^2 + g^2 t^2}}. \quad (8)$$

The radius of curvature is determined by the ratio:

$$\rho = \frac{v^2}{a_n} = \frac{(v_0^2 + g^2 t^2)^{3/2}}{v_0 g}. \quad (9)$$

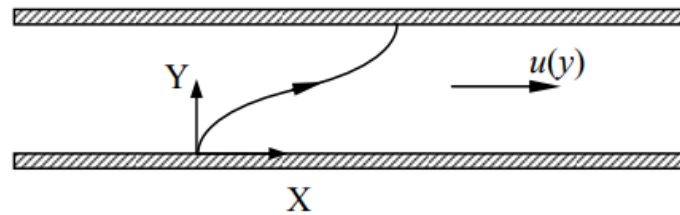
Note that in this problem all the formulas for finding the required quantities are valid from the initial moment of time $t_0 = 0$ until the moment the body falls to the Earth $t_0 \leq t \leq t_{\text{pd}}$. This moment in time is easy to find from the law of motion (4), taking the coordinate y equal to zero:

$$t_{\text{пад}} = \sqrt{\frac{2H}{g}}. \quad (10)$$

Problem 2. (Kinematics of a material point and the principle of superposition of movements). The boat crosses the river at a constant velocity v_l relative to the water, perpendicular to the direction of the river flow. The module of the flow velocity of the river, the width of which is d , increases from the banks to the middle of the river according to a parabolic law, varying from 0 to u_m . Find the equation of the trajectory of the boat, the time of its movement τ , as well as the drift of the boat l downstream from the place of its departure to the place of berthing on the opposite bank of the river [6-11].

Solution I. Let us choose a Cartesian coordinate system rigidly connected with the river bank and with the origin at the place where the boat sailed.

The axes of the coordinate system and the river flow velocity u (y) are shown in the figure.



When solving the problem, the boat will be considered a material point, and the river banks are parallel [12-17].

II. Let us write down the initial conditions for the boat in accordance with the conditions of the problem:

$$\begin{cases} x(0) = 0, y(0) = 0, \\ v_x(0) = 0, v_y(0) = v_{\pi}, \end{cases} \quad (11)$$

where v_x , v_y are the projections of the boat speed on the axis of the selected coordinate system. In accordance with the principle of superposition of movements at any time

$$\mathbf{v}(t) = \mathbf{u}(y(t)) + \mathbf{v}_{\pi}(t) \quad (12)$$

or in projections on the coordinate axes:

$$\begin{cases} v_x = u(y), \\ v_y = v_{\pi}. \end{cases} \quad (13)$$

According to the condition of the problem, the modulus of the flow velocity of the river, the width of which is d , increases from the banks to the middle of the river according to the parabolic law, therefore, we can write:

$$u(y) = a(y - d/2)^2 + b, \quad (14)$$

where a and b are constants. To determine the value of b , we use the condition of the problem:

$$b = u(y = d/2) = u_m. \quad (15)$$

Using the initial conditions:

$$v_x(0) = a \frac{d^2}{4} + b = 0$$

and relation (15), we obtain the value a

$$a = -\frac{4}{d^2} b = -\frac{4}{d^2} u_m. \quad (16)$$

III. The system of equations (13), taking into account (14) - (16), is transformed to the form:

$$\begin{cases} \frac{dx}{dt} = v_x = -\frac{4u_m}{d^2} y^2 + \frac{4u_m}{d} y, \\ \frac{dy}{dt} = v_y = v_{\pi}. \end{cases} \quad (17)$$

Integrating equations (17) taking into account the initial conditions for the boat coordinates (11), we find the law of motion:

$$x(t) = -\frac{4u_m}{d^2} v_{\pi}^2 \frac{t^3}{3} + \frac{2u_m}{d} v_{\pi} t^2, \quad (18)$$

$$y(t) = v_{\pi} t. \quad (19)$$

We obtain the trajectory equation, excluding the time t from the law of motion in coordinate form (18) and (19):

$$x(y) = \frac{4u_m}{3v_{\pi} d^2} \left(-y^3 + \frac{3}{2} y^2 d \right). \quad (20)$$

Since at the moment of mooring $y(\tau) = d$, the time of movement τ of the boat is equal to:

$$\tau = \frac{d}{v_{\pi}}. \quad (21)$$

Therefore, for the required demolition of the boat l , we obtain (see 20):

$$l = x(\tau) = \frac{2u_m}{3v_{\pi}} d. \quad (22)$$

Conclusion

And so, for students to develop the ability to solve physical problems, is the "Methodology for solving problems", which is compiled in such a way that it can be used for independent work [18-21]. All material is divided into several stages. The analysis of the tasks of all chapters is carried out according to a single scheme, and each chapter can be worked out independently of the others.

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